

Course Catalog

Course Catalog 2016-2017

Course Catalog 2015-2016

Course Catalog 2014-2015

Course Catalog 2013-2014

Course Catalog 2012-2013

Course Catalog 2011-2012

Course Catalog 2010-2011

Course Catalog 2009-2010

The Rose-Hulman Course Catalog is the document of record for all Programs of Study and Course Descriptions for any given academic year.

For earlier versions of the Rose-Hulman Course Catalog please contact the [Registrar's office](#).



Archived Course Descriptions

- 2001
- 2003
- 2005
- 2006
- 2007
- 2008



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Community Members

Industry Partners
Trustees
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Course Catalog

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Course Catalog 2015-2016

Course Catalog 2016-2017

Course Catalog 2015-2016

Course Catalog 2014-2015

Course Catalog 2013-2014

Course Catalog 2012-2013

Course Catalog 2011-2012

Course Catalog 2010-2011

Course Catalog 2009-2010

Welcome to the document of record for all Programs of Study and
Course Descriptions for the academic year 2015-2016.



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Current Students
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Faculty and Staff
Alumni and Friends
Community Members

- Industry Partners
- Trustees
- Parents

Course Catalog

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Course Catalog 2014-2015

- | |
|--|
| Course Catalog 2016-2017 |
| Course Catalog 2015-2016 |
| Course Catalog 2014-2015 |
| Course Catalog 2013-2014 |
| Course Catalog 2012-2013 |
| Course Catalog 2011-2012 |
| Course Catalog 2010-2011 |
| Course Catalog 2009-2010 |

Welcome to the document of record for all Programs of Study and Course Descriptions for the academic year 2014-2015.



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Information For

- | | | |
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| Prospective Students | Faculty and Staff | Industry Partners |
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| Incoming Freshman | Community Members | Parents |

Course Catalog

- Programs of Study
- Course Descriptions
- Minors
- Special Programs
- Advanced Placement
- Graduate Studies

CATALOG HOME

Course Catalog 2013-2014

Welcome to the document of record for all Programs of Study and Course Descriptions for the academic year 2013-2014.



- Course Catalog 2016-2017
- Course Catalog 2015-2016
- Course Catalog 2014-2015
- Course Catalog 2013-2014
- Course Catalog 2012-2013
- Course Catalog 2011-2012
- Course Catalog 2010-2011
- Course Catalog 2009-2010

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Information For

- Prospective Students
- Current Students
- Incoming Freshman
- Faculty and Staff
- Alumni and Friends
- Community Members
- Industry Partners
- Trustees
- Parents

Course Catalog

- [Programs of Study](#)
[Course Descriptions](#)
[Minors](#)
- [Special Programs](#)
[Advanced Placement](#)
[Graduate Studies](#)

[CATALOG HOME](#)

Course Catalog 2011-2012

Welcome to the document of record for all Programs of Study and Course Descriptions for the academic year 2011-2012.



- [Course Catalog 2016-2017](#)
- [Course Catalog 2015-2016](#)
- [Course Catalog 2014-2015](#)
- [Course Catalog 2013-2014](#)
- [Course Catalog 2012-2013](#)
- [Course Catalog 2011-2012](#)
- [Course Catalog 2010-2011](#)
- [Course Catalog 2009-2010](#)

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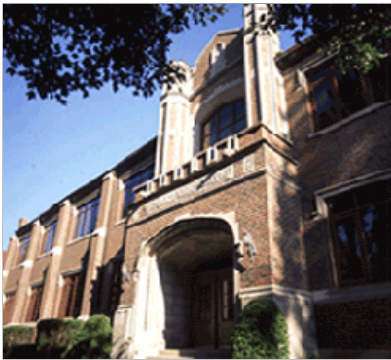
- [Prospective Students](#)
[Current Students](#)
[Incoming Freshman](#)
- [Faculty and Staff](#)
[Alumni and Friends](#)
[Community Members](#)
- [Industry Partners](#)
[Trustees](#)
[Parents](#)

Registrar

812-877-8298
lind@rose-hulman.edu

- Student RecordsRegistration ServicesFormsCalendars & SchedulesRules & ProceduresCourse CatalogLocation & Contact

Registrar's Office location and contact information



The Registrar's Office is located in Moench Hall, Room A218.

Contact information

Office of the Registrar
5500 Wabash Avenue
Terre Haute, IN 47803

Phone: 812-877-8298
Fax: 812-877-8141

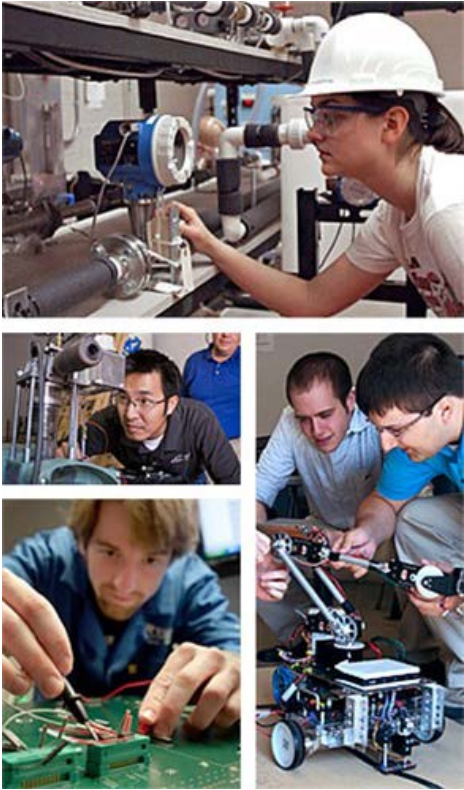
Staff

- Jan Pink, Registrar, 812-877-8297
- Karen Brimberry, Assistant Registrar, 812-877-8299
- Beverly Turner, Assistant to the Registrar, 812-877-8298

Programs of Study

Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5
PH	111	Physics I	4
PH	112	Physics II	4

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses.

Army ROTC (Military)

Pre-Professional Programs



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Current Students
Incoming Freshman

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Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2016-2017

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Course Descriptions

Course descriptions for various areas can be obtained by clicking on the links below.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics



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[Prospective Students](#)
[Current Students](#)
[Incoming Freshman](#)

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[Alumni and Friends](#)
[Community Members](#)

[Industry Partners](#)
[Trustees](#)
[Parents](#)

[Intranet](#) | [Contact Us](#) | [Banner Web](#) | [Map and Directions](#) | [Employment](#) | [Accessibility](#)

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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2016-2017

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Minors

TECHNICAL MINORS

- Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Chemistry
- Environmental Engineering
- Mathematics
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics
- Thermal Fluids

MULTIDISCIPLINARY MINOR

- Robotics
- Imaging

HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Modern Language
- Music



- [Philosophy and Religion](#)
- [Political Science](#)
- [Psychology](#)
- [Spanish](#)
- [Theatre and Drama](#)



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- [Incoming Freshman](#)

- [Faculty and Staff](#)
- [Alumni and Friends](#)
- [Community Members](#)

- [Industry Partners](#)
- [Trustees](#)
- [Parents](#)

Course Catalog 2016-2017

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Special Programs

- | | |
|---|---|
| <u>Fast Track Calculus</u> | <u>Multidisciplinary Minor in Imaging</u> |
| <u>Accelerated Math Physics</u> | <u>Certificate In Semiconductor Materials And Devices</u> |
| <u>New Student Orientation</u> | <u>The Management Studies Program</u> |
| <u>Consulting Engineering Program</u> | <u>German Technical Translator's Certificate Program</u> |
| <u>Foreign Studies Program</u> | <u>Multidisciplinary Minor in Robotics</u> |
| <u>Integrated Circuit Testing Certificate</u> | |

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete the Accelerated Math Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to the Accelerated Math Physics Program is competitive. Interested students should contact the Directors of the Accelerated Math Physics Program.

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in

academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CERTIFICATE IN SUSTAINABILITY STUDIES

The Certificate in Sustainability Studies, an interdisciplinary program open to Rose-Hulman students of all majors, will enhance students' understanding of the environmental, social, and economic dimensions of sustainability. Students will develop communication, professional, and design skills that will allow them to contribute to sustainability on local, national, and global levels.

The Certificate in Sustainability Studies consists of six required courses: a three-course core, two electives (one social and one technical or scientific), and a seminar credit. With the exception of the seminar, all of these courses are offered regularly by institute faculty.

Core Courses

GS130 Introduction to Sustainability

BIO/CHEM264 Introduction to Environmental Science (prerequisite: CHEM113)

SV354 Environmental Economics (prerequisite: SV151)

Seminar

MDS402 Seminar in Sustainability

Electives

Students must take a total of eight credits, at least four from each of the lists below.

Social

SV201 Religion and Ecology

SV303 Business and Engineering Ethics

SV304 Bioethics

SV322 Disasters and Modern Society

SV339 Literature and the Environment

Technical and Scientific

BIO320 Ecology

CE250 Sustainable Civil Engineering Design (2 credits)

CE460 Introduction to Environmental Engineering

CE471 Water Resources Engineering

CHEM Green Chemistry (Special Topics)

CHEM371 Environmental Analytical Chemistry

CHEM465 Environmental Organic Chemistry

CHE465 Energy and the Environment

ECE371 Sustainable Energy Systems

EM103 Introduction to Design (with performance of a sustainability project)

EMGT526 Innovation Management and Forecasting

MA387 Statistical Methods in Six Sigma (with performance of a sustainability project) (Pre:MA223 or MA382)

ME408 Renewable Energy

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. Kevin Sutterer P.E., Ph.D., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

INTEGRATED CIRCUIT TESTING CERTIFICATE

Testing integrated circuits is a critical element in the integrated circuit industry. In fact, testing has become the bottle-neck for many companies, with inefficient test programs preventing the release of products onto the market. With few colleges offering courses in this area, students at RHIT have a unique specialization opportunity, making them marketable and extremely valuable in the integrated circuit industry.

This certificate intends to provide the student with a solid background in test and product engineering and broaden that background with other courses pertinent to the test and product engineering field. A strong test/product engineer requires knowledge about integrated circuit design, systems design, board design, semiconductor fabrication, and statistics. Therefore, courses in these areas can be chosen for the elective portion of the certificate.

The test and product engineering certificate could be completed by an electrical or computer engineering student without overloading if the certificate courses are mapped to all but one of the Area, Technical, and Free electives. Electives have been chosen so that students can pursue the semiconductor certificate or a math minor in conjunction.

Certificate Requirements

ECE351: Analog Electronics is required.

Two of the three testing courses are required.

ECE557: Analog Test and Product Engineering

ECE558: Mixed-Signal Test and Product Engineering
ECE531: Digital Test and Product Engineering

Three of ten elective courses are required.

ECE551: Digital VLSI
ECE552: Analog Integrated Circuit Design
ECE553: RF Integrated Circuit Design
ECE343: High-Speed Digital Design (required for CPE program)
ECE416: Intro to MEMS
ECE419: Advanced MEMS
ECE454: System Level Analog Electronics
ECE557: Analog Test and Product Engineering (if not used for required testing course)
ECE558: Mixed-Signal Test and Product Engineering (if not used for required testing course)
ECE531: Digital Test and Product Engineering (if not used for required testing course)
PH405: Semiconductor Materials and Device I
EP406: Semiconductor Materials and Devices II
MA385: Quality Methods Engineering
MA387: Statistical Methods in Six Sigma

For further information about the certificate program, please contact Tina Hudson (HUDSON@rose-hulman.edu).

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)
ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)
OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)
CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)
CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)
CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)
ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)
ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)
MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)
MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)
OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)
OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)
ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)
BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

- Matt Boutell, Department of Computer Science and Software Engineering
- S. Allen Broughton, Department of Mathematics
- Robert M. Bunch, Department of Physics and Optical Engineering
- Kurt Bryan, Department of Mathematics
- Ed Doering, Department of Electrical and Computer Engineering
- David L. Finn, Department of Mathematics
- Charles Joenathan, Department of Physics and Optical Engineering
- Cary Laxer, Department of Computer Science and Software Engineering
- Michael F. McInerney, Department of Physics and Optical Engineering
- J.P. Mellor, Department of Computer Science and Software Engineering
- Xiaoyan Mu, Department of Electrical and Computer Engineering
- Wayne T. Padgett, Department of Electrical and Computer Engineering
- Deborah Walter, Department of Electrical and Computer Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (S. Kirkpatrick, Liptak, McInerney, Siahmakoun, Syed and Wagner). Students taking solid state/material science minor cannot take this certificate.

Required Courses

- 1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
 - 2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
 - 3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
- or:
- CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer

CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in “process” industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate’s academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America’s Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering

management. Courses not included in this list may be approved by the Management Studies Advisor:

CE303 Engineering Economy
SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
MAXXX Any statistics courses
EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR’S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- 1. A student must complete all the technical courses required by one of the Institute’s degree-granting programs.
- 2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
- 3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- 1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
- 2. In order to obtain the Translator’s Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4

<i>RH330 (required for most majors)</i>	<i>4</i>
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics, mechatronics, and assistive technologies. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman. Information about the minor can be found [here](#).

To earn the Multidisciplinary Minor in Robotics, a student needs to complete the three courses listed below plus additional courses listed below per the student's major.

Courses that all majors must complete [12 credit hours]

- CSSE120 Introduction to Software Development¹
- ME435/CSSE435 Robotics Engineering
- ECE425 Introduction to Mobile Robotics

¹ Note for ME and BE students: CSSE120 can be used as a course substitution for the required introduction to programming course (ME123 or BE100). However, ME and BE students may take both the required class AND CSSE120. CSSE120 will then count as a free elective.

In addition to the courses listed above students completing the robotics minor need to complete the courses below that apply to their major. (Students with a double major or double degree may choose which major to use. If a student decides to switch majors, that student must complete a track below appropriate for their final degree. These degree requirements are evaluated only at the time of your graduation.)

(1) CS and SE majors - Additional required courses:

- ME430 Mechatronic Systems
- 8 credits of Robo Electives (see list below)

(2) CPE majors - Additional required courses:

- CSSE463 Image Recognition
- 8 credits of Robo Electives (see list below)

(3) EE majors - Additional required courses:

- CSSE220 Object-Oriented Software Development
- 8 credits of Robo Electives (see list below)

(4) ME majors - Additional required courses

- CSSE220 Object-Oriented Software Development
- ME403 Kinematics of Machinery -or- ME497 Robot Dynamics and Control
- ME406 Control Systems²
- 4 credits of Robo Electives (see list below)

² Note, the list of additional required ME courses appears to be 1 course longer than other tracks, but ME students are required to take either Control Systems (ME406) or Vibration Analysis (EM406) already, so the requirement to take ME406 should not cause the ME track to be any longer.

(5) For majors not listed above - Additional required courses

- CSSE220 Object-Oriented Software Development
- ME430 Mechatronic Systems
- BE350 or ECE 320 or ME 406 [or a Controls course from any major]³
- 4 credits of Robo Electives (see list below)

³ For BE majors, a controls course will fill an area requirement. So, much like the ME track, the requirement to have a controls course should not cause this track to be longer for BE majors than tracks for other majors.

Robotics Electives

Students choose Robotics Electives from the list below subject to the restrictions that a student's Robotics Elective courses(s) cannot be any course listed above as an additional required course for the student's major, and cannot be a course listed as a named requirement for the student's major.

- BE350 Biocontrol Systems
- BE520 Brain Machine Interfaces
- BE543 Neuroprosthetics
- CSSE413 Artificial Intelligence
- CSSE480 Web App Frameworks with AppEngine
- CSSE483 Android Application Development
- CSSE484 iOS Application Development
- CSSE461 Computer Vision
- CSSE463 Image Recognition
- CSSE490 Swarm Intelligence
- CSSE290/490 Teamwork and Robotics
- CSSE290/490 Software Challenges in Robotics
- ECE320 Linear Controls
- ECE300 Continuous Time Signals and Systems
- ECE414 Wireless Systems
- ECE420 Discrete-time Control Systems
- ECE480/PH437 Image Processing
- ECE483 Digital Signal Processing System Design
- ECE582/PH537 Advanced Image Processing
- ECE583 Pattern Recognition
- IA471 Computational Psychology
- ME403 Kinematics of Machinery
- ME406 Control Systems
- ME497 Robot Dynamics and Control
- ME497 Three Dimensional Dynamics
- ME506 Advanced Control Sys
- ME518 Advanced Kinematics
- EM502 Advanced Dynamics
- EP408 Microsensors
- CSSE490/ME497/ECE497 Robotics Studio
- Independent study courses in robotics [requires approval BEFORE the course is taken]



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Faculty and Staff
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Industry Partners
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ROSE-HULMAN

INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2016-2017

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV (HSS SV Elective)
BIOLOGY	4	Score 4=BIO101; Score 5=BIO110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV152
ECON - MIC	4	SV150
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA (HSS IA Elective)
ENVIRONMENTAL SCIENCE	0	No credit
EUROPEAN HISTORY	4	GS (HSS GS Elective)
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang;

		Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs); Score 5=GE 111, GE 112, & GE 113 (12cr hrs)
GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B, or 1 and 2	0	No credit
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	No credit
STUDIO ART:3D DESIGN	4	No credit
US HISTORY	4	SV (HSS SV Elective)
WORLD HISTORY	4	GS223


TRANSFER STUDENTS

A student transferring from another college or university is required to be in "good academic standing." Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval

in advance from the head of the department concerned.



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Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

particular career. The course-based master's degree is more structured and focused on the knowledge and applications of a given field and is therefore considered as a professional degree.

Course-based Program Options:

- Chemical Engineering
- Chemistry/Biochemistry
- Civil Engineering
- Electrical and Computer Engineering
- Engineering Management
- Environmental Engineering
- Mechanical Engineering

Dual Master of Science Degrees

Students can earn two master of science degrees through dual degree programs Rose-Hulman Institute of Technology has established with Ulm University of Applied Sciences (Germany) and Seoul National University of Science and Technology (South Korea). Students study both at Rose-Hulman and the international university.

In the Ulm University program students will earn a master of science in systems engineering and management from their respective home institutions (Rose-Hulman or Ulm University of Applied Sciences). Students in the program with SeoulTech will be awarded a master of science degree in mechanical systems design engineering from SeoulTech and a master of science in optical engineering from Rose-Hulman.



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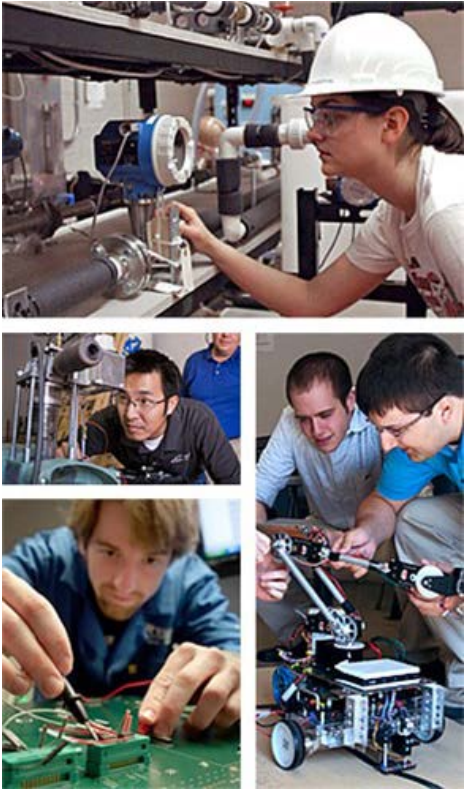
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[Parents](#)

Programs of Study

Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5
PH	111	Physics I	4
PH	112	Physics II	4

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses.

Army ROTC (Military)

Pre-Professional Programs



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Information For

Prospective Students
Current Students
Incoming Freshman

Faculty and Staff
Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2015-2016

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Course Descriptions

Course descriptions for various areas can be obtained by clicking on the links below.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics



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2017

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Prospective Students	Faculty and Staff	Industry Partners
Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

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- [Philosophy and Religion](#)
- [Political Science](#)
- [Psychology](#)
- [Spanish](#)
- [Theatre and Drama](#)



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- [Prospective Students](#)
- [Current Students](#)
- [Incoming Freshman](#)

- [Faculty and Staff](#)
- [Alumni and Friends](#)
- [Community Members](#)

- [Industry Partners](#)
- [Trustees](#)
- [Parents](#)

ROSE-HULMAN

INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2015-2016

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Special Programs

[Fast Track Calculus](#)

[Accelerated Math Physics](#)

[New Student Orientation](#)

[Consulting Engineering Program](#)

[Foreign Studies Program](#)

[Integrated Circuit Testing Certificate](#)

[Multidisciplinary Minor in Imaging](#)

[Certificate In Semiconductor Materials And Devices](#)

[The Management Studies Program](#)

[German Technical Translator's Certificate Program](#)

[Multidisciplinary Minor in Robotics](#)

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

ACCELERATED MATH PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete the Accelerated Math Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to the Accelerated Math Physics Program is competitive. Interested students should contact the Directors of the Accelerated Math Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in

academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CERTIFICATE IN SUSTAINABILITY STUDIES

The Certificate in Sustainability Studies, an interdisciplinary program open to Rose-Hulman students of all majors, will enhance students' understanding of the environmental, social, and economic dimensions of sustainability. Students will develop communication, professional, and design skills that will allow them to contribute to sustainability on local, national, and global levels.

The Certificate in Sustainability Studies consists of six required courses: a three-course core, two electives (one social and one technical or scientific), and a seminar credit. With the exception of the seminar, all of these courses are offered regularly by institute faculty.

Core Courses

- GS130 Introduction to Sustainability
- BIO/CHEM264 Introduction to Environmental Science (prerequisite: CHEM113)
- SV354 Environmental Economics (prerequisite: SV151)

Seminar

- MDS420 Seminar in Sustainability

Electives

Students must take a total of eight credits, at least four from each of the lists below.

Social

- SV201 Religion and Ecology
- SV303 Business and Engineering Ethics
- SV304 Bioethics
- SV322 Disasters and Modern Society
- SV339 Literature and the Environment

Technical and Scientific

- BIO320 Ecology
- CE250 Sustainable Civil Engineering Design (2 credits)
- CE460 Introduction to Environmental Engineering
- CE471 Water Resources Engineering
- CHEM Green Chemistry (Special Topics)
- CHEM371 Environmental Analytical Chemistry
- CHEM465 Environmental Organic Chemistry
- CHE465 Energy and the Environment
- ECE371 Sustainable Energy Systems
- EM103 Introduction to Design (with performance of a sustainability project)
- EMGT526 Innovation Management and Forecasting
- MA387 Statistical Methods in Six Sigma (with performance of a sustainability project) (Pre:MA223 or MA382)
- ME408 Renewable Energy

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. Kevin Sutterer P.E., Ph.D., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

INTEGRATED CIRCUIT TESTING CERTIFICATE

Testing integrated circuits is a critical element in the integrated circuit industry. In fact, testing has become the bottle-neck for many companies, with inefficient test programs preventing the release of products onto the market. With few colleges offering courses in this area, students at RHIT have a unique specialization opportunity, making them marketable and extremely valuable in the integrated circuit industry.

This certificate intends to provide the student with a solid background in test and product engineering and broaden that background with other courses pertinent to the test and product engineering field. A strong test/product engineer requires knowledge about integrated circuit design, systems design, board design, semiconductor fabrication, and statistics. Therefore, courses in these areas can be chosen for the elective portion of the certificate.

The test and product engineering certificate could be completed by an electrical or computer engineering student without overloading if the certificate courses are mapped to all but one of the Area, Technical, and Free electives. Electives have been chosen so that students can pursue the semiconductor certificate or a math minor in conjunction.

Certificate Requirements

ECE351: Analog Electronics is required.

Two of the three testing courses are required.

ECE557: Analog Test and Product Engineering

ECE558: Mixed-Signal Test and Product Engineering
ECE531: Digital Test and Product Engineering

Three of ten elective courses are required.

ECE551: Digital VLSI
ECE552: Analog Integrated Circuit Design
ECE553: RF Integrated Circuit Design
ECE343: High-Speed Digital Design (required for CPE program)
ECE416: Intro to MEMS
ECE419: Advanced MEMS
ECE454: System Level Analog Electronics
ECE557: Analog Test and Product Engineering (if not used for required testing course)
ECE558: Mixed-Signal Test and Product Engineering (if not used for required testing course)
ECE531: Digital Test and Product Engineering (if not used for required testing course)
PH405: Semiconductor Materials and Device I
EP406: Semiconductor Materials and Devices II
MA385: Quality Methods Engineering
MA387: Statistical Methods in Six Sigma

For further information about the certificate program, please contact Tina Hudson (HUDSON@rose-hulman.edu).

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)
ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)
OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)
Elective Courses (choose 2 that are not named courses required for your major)
CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)
CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)
CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)
CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)
ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)
ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)
MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)
MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)
OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)
OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)
ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)
BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

- Matt Boutell, Department of Computer Science and Software Engineering
- S. Allen Broughton, Department of Mathematics
- Robert M. Bunch, Department of Physics and Optical Engineering
- Kurt Bryan, Department of Mathematics
- Ed Doering, Department of Electrical and Computer Engineering
- David L. Finn, Department of Mathematics
- Charles Joenathan, Department of Physics and Optical Engineering
- Cary Laxer, Department of Computer Science and Software Engineering
- Michael F. McNerney, Department of Physics and Optical Engineering
- J.P. Mellor, Department of Computer Science and Software Engineering
- Xiaoyan Mu, Department of Electrical and Computer Engineering
- Wayne T. Padgett, Department of Electrical and Computer Engineering
- Deborah Walter, Department of Electrical and Computer Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (Professors McNerney, Siahmakoun, Wagner, and Syed). Students taking solid state/material science minor cannot take this certificate.

Required Courses

- 1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
 - 2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
 - 3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
- or:
- CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer

CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in "process" industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering

management. Courses not included in this list may be approved by the Management Studies Advisor:

- CE303 Engineering Economy
- SV353 Industrial Organization
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- GS350 International Trade: Globalization
- GS351 International Finance
- CE441 Construction Engineering
- CE442 Cost Engineering
- MA444 Deterministic Models in Operations Research
- MA445 Stochastic Models in Operations Research
- CSSEXXX Courses beyond CSSE 120 in Computer Science
- MAXXX Any statistics courses
- EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR’S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. A student must complete all the technical courses required by one of the Institute’s degree-granting programs.
2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
2. In order to obtain the Translator’s Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4

<i>RH330 (required for most majors)</i>	<i>4</i>
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics, mechatronics, and assistive technologies. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman. Information about the minor can be found [here](#).

To earn the Multidisciplinary Minor in Robotics, a student needs to complete the three courses listed below plus additional courses listed below per the student's major.

Courses that all majors must complete [12 credit hours]

- CSSE120 Introduction to Software Development¹
- ME435/CSSE435 Robotics Engineering
- ECE425 Introduction to Mobile Robotics

¹ Note for ME and BE students: CSSE120 can be used as a course substitution for the required introduction to programming course (ME123 or BE100). However, ME and BE students may take both the required class AND CSSE120. CSSE120 will then count as a free elective.

In addition to the courses listed above students completing the robotics minor need to complete the courses below that apply to their major. (Students with a double major or double degree may choose which major to use. If a student decides to switch majors, that student must complete a track below appropriate for their final degree. These degree requirements are evaluated only at the time of your graduation.)

Additional required courses for CS and SE majors

- ME430 Mechatronic Systems
- 8 credits of Robo Electives (see list below)

Additional required courses for CPE majors

- CSSE463 Image Recognition
- 8 credits of Robo Electives (see list below)

Additional required courses for EE majors

- CSSE220 Object-Oriented Software Development
- 8 credits of Robo Electives (see list below)

Additional required courses for ME majors:

- CSSE220 Object-Oriented Software Development
- ME403 Kinematics of Machinery
- ME406 Control Systems²
- 4 credits of Robo Electives (see list below)

² Note, the list of additional required ME courses appears to be 1 course longer than other tracks, but ME students are required to take either Control Systems (ME406) or Vibration Analysis (EM406) already, so the requirement to take ME406 should not cause the ME track to be any longer.

Additional required courses for majors not listed above

- CSSE220 Object-Oriented Software Development
- ME430 Mechatronic Systems
- BE350 or ECE 320 or ME 406 [or a Controls course from any major]³
- 4 credits of Robo Electives (see list below)

³ For BE majors, a controls course will fill an area requirement. So, much like the ME track, the requirement to have a controls course should not cause this track to be longer for BE majors than tracks for other majors.

Robotics Electives

Students choose Robotics Electives from the list below subject to the restrictions that a student's Robotics Elective courses(s) cannot be any course listed above as an additional required course for the student's major, and cannot be a course listed as a named requirement for the student's major.

- CSSE413 Artificial Intelligence
- CSSE461 Computer Vision
- CSSE463 Image Recognition
- CSSE490 Swarm Intelligence
- CSSE290/490 Teamwork and Robotics
- CSSE290/490 Software Challenges in Robotics
- ECE320 Linear Controls
- ECE300 Continuous Time Signals and Systems
- ECE414 Wireless Systems
- ECE420 Discrete-time Control Systems
- ECE480/PH437 Image Processing
- ECE483 Digital Signal Processing System Design
- ECE582/PH537 Advanced Image Processing
- ECE583 Pattern Recognition
- ME403 Kinematics of Machinery
- ME406 Control Systems
- ME506 Advanced Control Sys
- ME518 Advanced Kinematics
- EM502 Advanced Dynamics
- EP408 Microsensors
- BE543 Neuroprosthetics
- BE520 Brain Machine Interfaces
- BE350 Biocontrol Systems
- CSSE480 Web App Frameworks with AppEngine
- CSSE483 Android Application Development
- CSSE484 iOS Application Development
- CSSE490/ME497/ECE497 Robotics Studio
- Independent study courses in robotics [requires approval BEFORE the course is taken]



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Information For

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ROSE-HULMAN

INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2015-2016

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV (HSS SV Elective)
BIOLOGY	4	Score 4=BIO101; Score 5=BIO110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV152
ECON - MIC	4	SV150
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA (HSS IA Elective)
ENVIRONMENTAL SCIENCE	0	No credit
EUROPEAN HISTORY	4	GS (HSS GS Elective)
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang;

		Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs); Score 5=GE 111, GE 112, & GE 113 (12cr hrs)
GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B, or 1 and 2	0	No credit
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	No credit
STUDIO ART:3D DESIGN	4	No credit
US HISTORY	4	SV (HSS SV Elective)
WORLD HISTORY	4	GS223


TRANSFER STUDENTS

A student transferring from another college or university is required to be in "good academic standing." Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval

in advance from the head of the department concerned.



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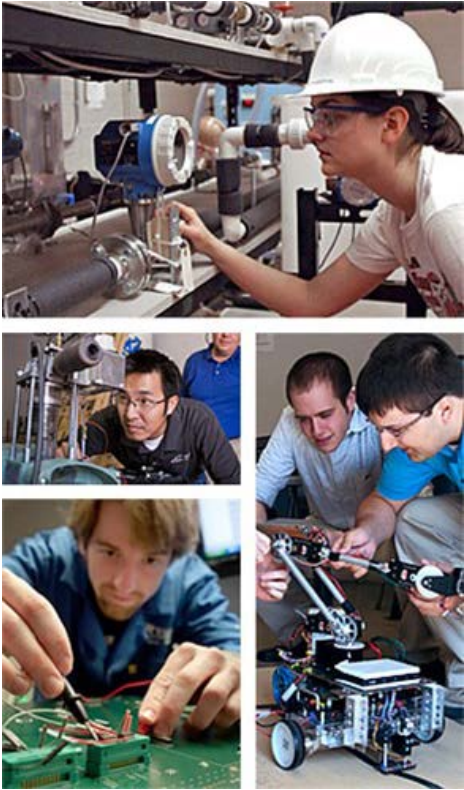


Information For

Prospective Students	Faculty and Staff	Industry Partners
Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5
PH	111	Physics I	4
PH	112	Physics II	4

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses.

Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

Pre-Professional Programs



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Prospective Students
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Faculty and Staff
Alumni and Friends
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Industry Partners
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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2014-2015

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Minors

TECHNICAL MINORS

- Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Chemistry
- Environmental Engineering
- Mathematics
- Mechanical Engineering (Thermal Fluids)
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics

MULTIDISCIPLINARY MINOR

- Robotics
- Imaging

HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Modern Language
- Music
- Philosophy and Religion



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Course Catalog 2014-2015

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Special Programs

<u>Fast Track Calculus</u>	<u>Multidisciplinary Minor in Imaging</u>
<u>Accelerated Math Physics</u>	<u>Certificate In Semiconductor Materials And Devices</u>
<u>New Student Orientation</u>	<u>The Management Studies Program</u>
<u>Consulting Engineering Program</u>	<u>German Technical Translator's Certificate Program</u>
<u>Foreign Studies Program</u>	<u>Multidisciplinary Minor in Robotics</u>

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

ACCELERATED MATH PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete the Accelerated Math Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to the Accelerated Math Physics Program is competitive. Interested students should contact the Directors of the Accelerated Math Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CERTIFICATE IN SUSTAINABILITY STUDIES

The Certificate in Sustainability Studies, an interdisciplinary program open to Rose-Hulman students of all majors, will enhance students' understanding of the environmental, social, and economic dimensions of sustainability. Students will develop communication, professional, and design skills that will allow them to contribute to sustainability on local, national, and global levels.

The Certificate in Sustainability Studies consists of six required courses: a three-course core, two electives (one social and one technical or scientific), and a seminar credit. With the exception of the seminar, all of these courses are offered regularly by institute faculty.

Core Courses

- GS130 Introduction to Sustainability
- BIO/CHEM264 Introduction to Environmental Science (prerequisite: CHEM113)
- SV354 Environmental Economics (prerequisite: SV151)

Seminar

- MDS420 Seminar in Sustainability

Electives

Students must take a total of eight credits, at least four from each of the lists below.

Social

- SV201 Religion and Ecology
- SV303 Business and Engineering Ethics
- SV304 Bioethics
- SV322 Disasters and Modern Society
- SV339 Literature and the Environment

Technical and Scientific

- BIO320 Ecology
- CE250 Sustainable Civil Engineering Design (2 credits)
- CE460 Introduction to Environmental Engineering
- CE471 Water Resources Engineering
- CHEM Green Chemistry (Special Topics)
- CHEM371 Environmental Analytical Chemistry
- CHEM465 Environmental Organic Chemistry
- CHE465 Energy and the Environment
- ECE371 Sustainable Energy Systems
- EM103 Introduction to Design (with performance of a sustainability project)
- EMGT526 Innovation Management and Forecasting
- MA387 Statistical Methods in Six Sigma (with performance of a sustainability project) (Pre:MA223 or MA382)
- ME408 Renewable Energy

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology.

Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. Kevin Sutterer P.E., Ph.D., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)

ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)

OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)

CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)

CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)

CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)

ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)

ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)

MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)

MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)

OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)

OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)

ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)

BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

Matt Boutell, Department of Computer Science and Software Engineering

S. Allen Broughton, Department of Mathematics

Robert M. Bunch, Department of Physics and Optical Engineering

Kurt Bryan, Department of Mathematics

Ed Doering, Department of Electrical and Computer Engineering

David L. Finn, Department of Mathematics

Charles Joenathan, Department of Physics and Optical Engineering

Cary Laxer, Department of Computer Science and Software Engineering

Michael F. McInerney, Department of Physics and Optical Engineering

J.P. Mellor, Department of Computer Science and Software Engineering

Xiaoyan Mu, Department of Electrical and Computer Engineering

Wayne T. Padgett, Department of Electrical and Computer Engineering

Deborah Walter, Department of Electrical and Computer Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (Professors McInerney, Siahmakoun, Wagner, and Syed). Students taking solid state/material science minor cannot take this certificate.

Required Courses

1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
or:
CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer
CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in "process" industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication

SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics

2. Two of the following Management in Society Courses (in addition to the core courses):

SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting

3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering management. Courses not included in this list may be approved by the Management Studies Advisor:

CE303 Engineering Economy
SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
MAXXX Any statistics courses
EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR'S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. *A student must complete all the technical courses required by one of the Institute's degree-granting programs.*
2. *A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.*
3. *A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).*

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

1. *A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.*
2. *In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.*

- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics, mechatronics, and assistive technologies. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman. Information about the minor, including degree requirements, can be found [here](#).



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Information For

Prospective Students
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Incoming Freshman

Faculty and Staff
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[About](#) | [Admissions](#) | [Academics](#) | [Student Life](#) | [News](#) | [Calendars](#) | [Alumni](#) | [Athletics](#)

[Offices and Services](#)

Course Catalog 2014-2015

[CATALOG HOME](#)

[Programs of Study](#)

[Course Descriptions](#)

[Minors](#)

[Special Programs](#)

[Advanced Placement](#)

[Graduate Studies](#)

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV (HSS SV Elective)
BIOLOGY	4	Score 4=BIO101; Score 5=BIO110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV151 (SV if granted SV151 for other econ exam)
ECON - MIC	4	SV151 (SV if granted SV151 for other econ exam)
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA (HSS IA Elective)
ENVIRONMENTAL SCIENCE	0	No credit
EUROPEAN HISTORY	4	GS (HSS GS Elective)
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang;

		Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs); Score 5=GE 111, GE 112, & GE 113 (12cr hrs)
GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B	0	No credit
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	No credit
STUDIO ART:3D DESIGN	4	No credit
US HISTORY	4	SV (HSS SV Elective)
WORLD HISTORY	4	GS223

TRANSFER STUDENTS

A student transferring from another college or university is required to be in "good academic standing." Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval

in advance from the head of the department concerned.



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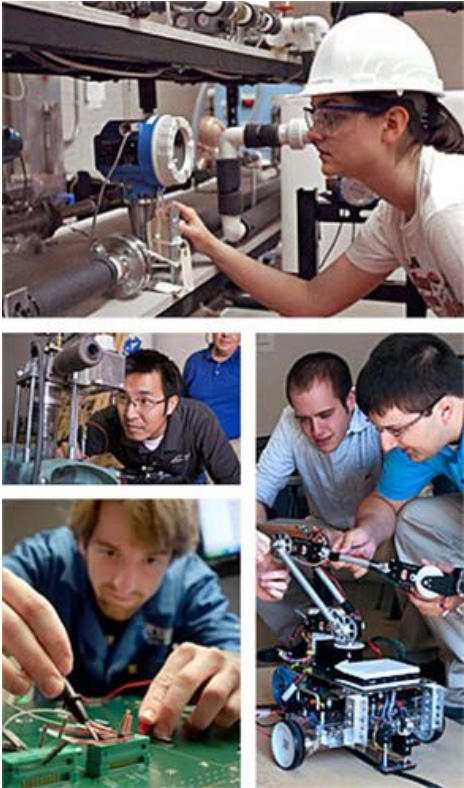
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[Community Members](#)

[Industry Partners](#)
[Trustees](#)
[Parents](#)

Programs of Study

Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5
PH	111	Physics I	4
PH	112	Physics II	4

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses.



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[Parents](#)

Prospective Students	Faculty and Staff	Industry Partners
Current Students	Alumni and Friends	Trustees
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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2013-2014

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Minors

TECHNICAL MINORS

- Applied Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Chemistry
- Environmental Engineering
- Mathematics
- Mechanical Engineering (Thermal Fluids)
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics

MULTIDISCIPLINARY MINOR

- Robotics
- Imaging

HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Music
- Philosophy and Religion
- Political Science



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[Incoming Freshman](#)

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[Alumni and Friends](#)
[Community Members](#)

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[Trustees](#)
[Parents](#)

[Intranet](#) | [Contact Us](#) | [Banner Web](#) | [Map and Directions](#) | [Employment](#) | [Accessibility](#)

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Course Catalog 2013-2014

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Special Programs

<u>Fast Track Calculus</u>	<u>Multidisciplinary Minor in Imaging</u>
<u>Accelerated Math Physics</u>	<u>Certificate In Semiconductor Materials And Devices</u>
<u>New Student Orientation</u>	<u>The Management Studies Program</u>
<u>Consulting Engineering Program</u>	<u>German Technical Translator's Certificate Program</u>
<u>Foreign Studies Program</u>	<u>Multidisciplinary Minor in Robotics</u>

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

ACCELERATED MATH PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete the Accelerated Math Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to Accelerated Math Physics is competitive. Interested students should contact the Directors of the Accelerated Math Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. James L. McKinney P.E., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

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on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)

ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)

OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)

CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)

CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)

CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)

ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)

ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)

MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)

MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)

OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)

OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)

ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)

BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

Matt Boutell, Department of Computer Science and Software Engineering

S. Allen Broughton, Department of Mathematics

Robert M. Bunch, Department of Physics and Optical Engineering

Kurt Bryan, Department of Mathematics

Ed Doering, Department of Electrical and Computer Engineering

David L. Finn, Department of Mathematics

Charles Joenathan, Department of Physics and Optical Engineering

Cary Laxer, Department of Computer Science and Software Engineering

Michael F. McNerney, Department of Physics and Optical Engineering

J.P. Mellor, Department of Computer Science and Software Engineering

Xiaoyan Mu, Department of Electrical and Computer Engineering

Wayne T. Padgett, Department of Electrical and Computer Engineering
Deborah Walter, Department of Electrical and Computer Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (Professors McInerney, Siahmakoun, Wagner, and Syed). Students taking solid state/material science minor cannot take this certificate.

Required Courses

- 1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
- 2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
- 3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
or:
CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer
CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in "process" industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering management. Courses not included in this list may be approved by the Management Studies Advisor:
CE303 Engineering Economy
SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
MAXXX Any statistics courses
EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR'S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. *A student must complete all the technical courses required by one of the Institute's degree-granting programs.*

- 2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
- 3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- 1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
- 2. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics and mechatronics. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman.

Students earning the minor must satisfy three requirements. (1) They must major in one of the following areas: Mechanical Engineering, Electrical Engineering, Computer Engineering, Computer Science, or Software Engineering to obtain depth. (2) They must complete one of the 28-credit tracks ([PDF of curriculum tracks](#)) to obtain breadth in a second area. (3) They must work on a multidisciplinary robotics senior design project by taking ROBO 410, ROBO 420, and ROBO 430. Exceptions to the robotics minor requirements require approval of the appropriate robotics advisor (below).

Students wanting to pursue the minor should complete a declaration-of-intent form and submit it to the appropriate track advisor. Completion of the program will be noted on the student's official transcript but not on the diploma. The advisors are Dr. Matthew Boutell (CSSE tracks), Dr. Carlotta Berry (ECE tracks), and Dr. David Fisher (ME tracks). Additional information about the minor can be found [here](#).





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Course Catalog 2013-2014

- [Programs of Study](#)
[Course Descriptions](#)
[Minors](#)
- [Special Programs](#)
[Advanced Placement](#)
[Graduate Studies](#)

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV (HSS SV Elective)
BIOLOGY	4	Score 4=AB101; Score 5=AB110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV151 (SV if granted SV151 for other econ exam)
ECON - MIC	4	SV151 (SV if granted SV151 for other econ exam)
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA (HSS IA Elective)
ENVIRONMENTAL SCIENCE	0	No credit
EUROPEAN HISTORY	4	GS (HSS GS Elective)
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang;

		Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs); Score 5=GE 111, GE 112, & GE 113 (12cr hrs)
GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B	0	No credit
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	No credit
STUDIO ART:3D DESIGN	4	No credit
US HISTORY	4	SV (HSS SV Elective)
WORLD HISTORY	4	GS223

TRANSFER STUDENTS

A student transferring from another college or university is required to be in "good academic standing." Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval

in advance from the head of the department concerned.



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Institute of Technology**
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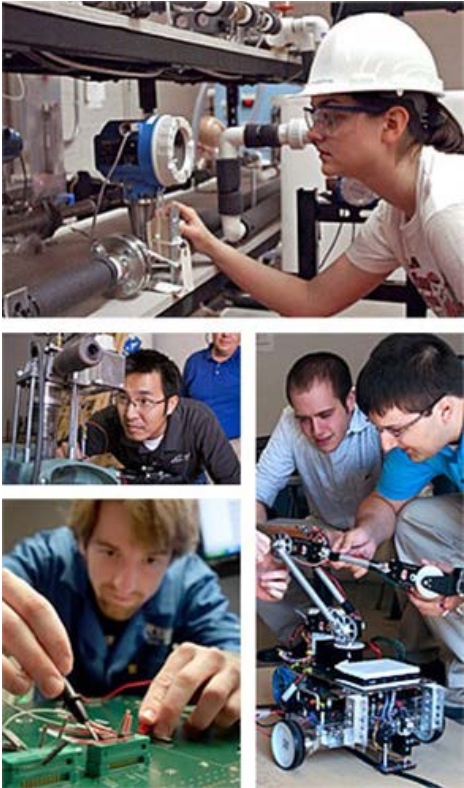
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Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5
PH	111	Physics I	4
PH	112	Physics II	4

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses. The requirement for MA 111 may be fulfilled by MA 101 and 102 in certain cases.



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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2012-2013

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Minors

TECHNICAL MINORS

- Applied Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Chemistry
- Environmental Engineering
- Mathematics
- Mechanical Engineering (Thermal Fluids)
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics

MULTIDISCIPLINARY MINOR

- Robotics
- Imaging

HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Music
- Philosophy and Religion
- Political Science



[Psychology](#)
[Spanish](#)



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[Incoming Freshman](#)

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[Alumni and Friends](#)
[Community Members](#)

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[Trustees](#)
[Parents](#)

[Intranet](#) | [Contact Us](#) | [Banner Web](#) | [Map and Directions](#) | [Employment](#) | [Accessibility](#)

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Course Catalog 2012-2013

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Special Programs

Fast Track Calculus

Multidisciplinary Minor in Imaging

Fast Physics

Certificate In Semiconductor Materials And Devices

New Student Orientation

The Management Studies Program

Consulting Engineering Program

German Technical Translator's Certificate Program

Foreign Studies Program

Multidisciplinary Minor in Robotics

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

FAST PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to Fast Physics is competitive. Interested students should contact the Directors of the Fast Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. James L. McKinney P.E., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-

on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)

ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)

OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)

CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)

CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)

CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)

ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)

ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)

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MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)

OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)

OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)

ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)

BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

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Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

Matt Boutell, Department of Computer Science and Software Engineering

S. Allen Broughton, Department of Mathematics

Robert M. Bunch, Department of Physics and Optical Engineering

Kurt Bryan, Department of Mathematics

Ed Doering, Department of Electrical and Computer Engineering

David L. Finn, Department of Mathematics

Charles Joenathan, Department of Physics and Optical Engineering

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Xiaoyan Mu, Department of Electrical and Computer Engineering

Wayne T. Padgett, Department of Electrical and Computer Engineering
Deborah Walter, Department of Electrical and Computer Engineering
Huihui Xu, Department of Applied Biology and Biomedical Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (Professors McInerney, Siahmakoun, Wagner, and Syed). Students taking solid state/material science minor cannot take this certificate.

Required Courses

- 1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
- 2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
- 3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
or:
CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer
CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in "process" industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering management. Courses not included in this list may be approved by the Management Studies Advisor:
CE303 Engineering Economy
SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
MAXXX Any statistics courses
EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR'S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. *A student must complete all the technical courses required by one of the Institute's degree-granting programs.*

- 2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
- 3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- 1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
- 2. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics and mechatronics. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman.

Students earning the minor must satisfy three requirements. (1) They must major in one of the following areas: Mechanical Engineering, Electrical Engineering, Computer Engineering, Computer Science, or Software Engineering to obtain depth. (2) They must complete one of the 28-credit tracks ([PDF of curriculum tracks](#)) to obtain breadth in a second area. (3) They must work on a multidisciplinary robotics senior design project by taking ROBO 410, ROBO 420, and ROBO 430. Exceptions to the robotics minor requirements require approval of the appropriate robotics advisor (below).

Students wanting to pursue the minor should complete a declaration-of-intent form and submit it to the appropriate track advisor. Completion of the program will be noted on the student's official transcript but not on the diploma. The advisors are Dr. Matthew Boutell (CSSE tracks), Dr. Carlotta Berry (ECE tracks), and Dr. David Fisher (ME tracks).

Additional information about the minor can be found [here](#).



Terre Haute, IN 47803
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Information For

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Course Catalog 2012-2013

- [Programs of Study](#)
[Course Descriptions](#)
[Minors](#)
- [Special Programs](#)
[Advanced Placement](#)
[Graduate Studies](#)

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV
BIOLOGY	4	Score 4=AB101; Score 5=AB110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV151 (SV if granted SV151 for other econ exam)
ECON - MIC	4	SV151 (SV if granted SV151 for other econ exam)
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA
ENVIRONMENTAL SCIENCE	0	NONE
EUROPEAN HISTORY	4	GS
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs);

Score 5=GE 111, GE 112, & GE 113 (12cr hrs)

GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B	0	NONE
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	no credit
STUDIO ART:3D DESIGN	4	no credit
US HISTORY	4	SV
WORLD HISTORY	4	GS223

TRANSFER STUDENTS

A student transferring from another college or university is required to be in “good academic standing.” Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval in advance from the head of the department concerned.



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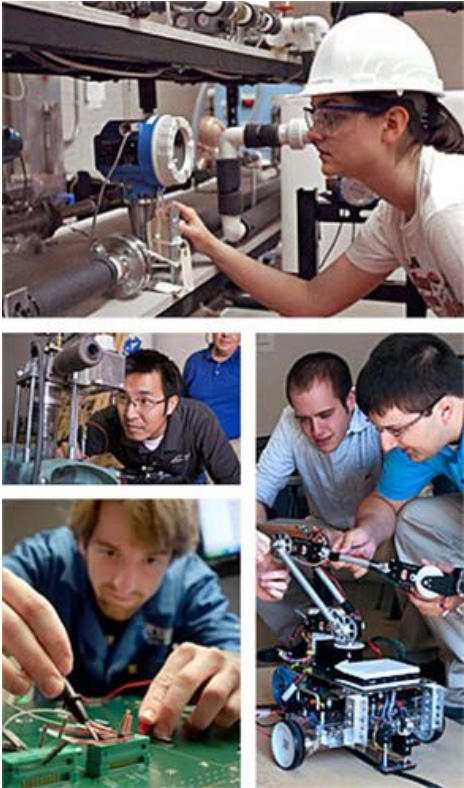
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Programs of Study

Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5
PH	111	Physics I	4
PH	112	Physics II	4

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses. The requirement for MA 111 may be fulfilled by MA 101 and 102 in certain cases.



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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2011-2012

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Minors

TECHNICAL MINORS

- Applied Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Chemistry
- Environmental Engineering
- Mathematics
- Mechanical Engineering (Thermal Fluids)
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics

MULTIDISCIPLINARY MINOR

- Robotics
- Imaging

HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Music
- Philosophy and Religion
- Political Science



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[Spanish](#)



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Course Catalog 2011-2012

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Special Programs

<u>Fast Track Calculus</u>	<u>Multidisciplinary Minor in Imaging</u>
<u>Fast Physics</u>	<u>Certificate In Semiconductor Materials And Devices</u>
<u>New Student Orientation</u>	<u>The Management Studies Program</u>
<u>Consulting Engineering Program</u>	<u>German Technical Translator's Certificate Program</u>
<u>Foreign Studies Program</u>	<u>Multidisciplinary Minor in Robotics</u>

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

FAST PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to Fast Physics is competitive. Interested students should contact the Directors of the Fast Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. James L. McKinney P.E., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-

on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)

ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)

OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)

CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)

CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)

CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)

ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)

ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)

MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)

MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)

OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)

OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)

ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)

BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

Matt Boutell, Department of Computer Science and Software Engineering

S. Allen Broughton, Department of Mathematics

Robert M. Bunch, Department of Physics and Optical Engineering

Kurt Bryan, Department of Mathematics

Ed Doering, Department of Electrical and Computer Engineering

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or:
CHE440 Process Control 4R-0L-4C W Pre: CHE202

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OE 485	4	Electro-Optics and Applications
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PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer
CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in “process” industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering management. Courses not included in this list may be approved by the Management Studies Advisor:
CE303 Engineering Economy
SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
MAXXX Any statistics courses
EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR'S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. *A student must complete all the technical courses required by one of the Institute's degree-granting programs.*

- 2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
- 3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- 1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
- 2. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics and mechatronics. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman.

Students earning the minor must satisfy three requirements. (1) They must major in one of the following areas: Mechanical Engineering, Electrical Engineering, Computer Engineering, Computer Science, or Software Engineering to obtain depth. (2) They must complete one of the 28-credit tracks ([PDF of curriculum tracks](#)) to obtain breadth in a second area. (3) They must work on a multidisciplinary robotics senior design project by taking ROBO 410, ROBO 420, and ROBO 430. Exceptions to the robotics minor requirements require approval of the appropriate robotics advisor (below).

Students wanting to pursue the minor should complete a declaration-of-intent form and submit it to the appropriate track advisor. Completion of the program will be noted on the student's official transcript but not on the diploma. The advisors are Dr. Matthew Boutell (CSSE tracks), Dr. Carlotta Berry (ECE tracks), and Dr. David Fisher (ME tracks).

Additional information about the minor can be found at <http://robotics.rose-hulman.edu>



Terre Haute, IN 47803
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Information For

Prospective Students
Current Students
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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2011-2012

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV
BIOLOGY	4	Score 4=AB101; Score 5=AB110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV151 (SV if granted SV151 for other econ exam)
ECON - MIC	4	SV151 (SV if granted SV151 for other econ exam)
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA
ENVIRONMENTAL SCIENCE	0	NONE
EUROPEAN HISTORY	4	GS
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs);

Score 5=GE 111, GE 112, & GE 113 (12cr hrs)

GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B	0	NONE
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	no credit
STUDIO ART:3D DESIGN	4	no credit
US HISTORY	4	SV
WORLD HISTORY	4	GS223

TRANSFER STUDENTS

A student transferring from another college or university is required to be in “good academic standing.” Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval in advance from the head of the department concerned.





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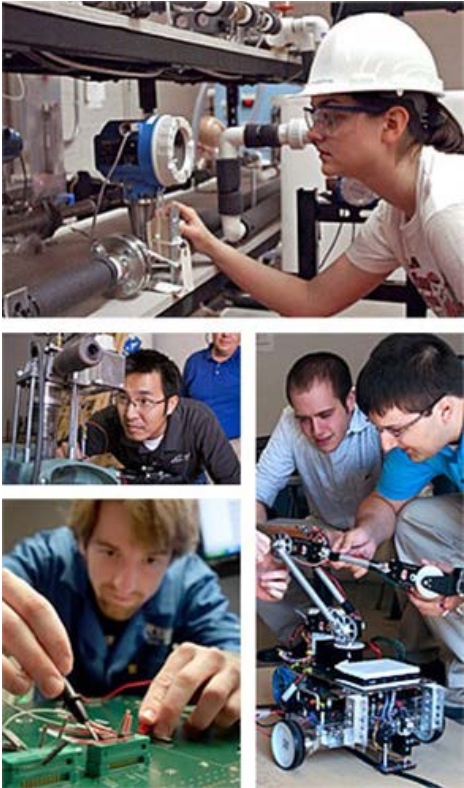
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[Trustees](#)
[Parents](#)

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Programs of study leading to a Bachelor of Science degree are available in the following areas:

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering



Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective	4
MA	111	Calculus I	5
MA	112	Calculus II	5
MA	113	Calculus III	5

Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses. The requirement for MA 111 may be fulfilled by MA 101 and 102 in certain cases.



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[Incoming Freshman](#)

[Faculty and Staff](#)
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[Industry Partners](#)
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[Parents](#)

Prospective Students	Faculty and Staff	Industry Partners
Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

[Intranet](#) | [Contact Us](#) | [Banner Web](#) | [Map and Directions](#) | [Employment](#) | [Accessibility](#)

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ROSE-HULMAN

INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2010-2011

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Minors

TECHNICAL MINORS

- Applied Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Chemistry
- Environmental Engineering
- Mathematics
- Mechanical Engineering (Thermal Fluids)
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics

MULTIDISCIPLINARY MINOR

- Robotics
- Imaging

HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Music
- Philosophy and Religion
- Political Science



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[Current Students](#)
[Incoming Freshman](#)

[Faculty and Staff](#)
[Alumni and Friends](#)
[Community Members](#)

[Industry Partners](#)
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[Parents](#)

[Intranet](#) | [Contact Us](#) | [Banner Web](#) | [Map and Directions](#) | [Employment](#) | [Accessibility](#)

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Special Programs

- [Fast Track Calculus](#)[Fast Physics](#)[New Student Orientation](#)[Consulting Engineering Program](#)[Foreign Studies Program](#)
- [Multidisciplinary Minor in Imaging](#)[Certificate In Semiconductor Materials And Devices](#)[The Management Studies Program](#)[German Technical Translator's Certificate Program](#)[Multidisciplinary Minor in Robotics](#)

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

FAST PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to Fast Physics is competitive. Interested students should contact the Directors of the Fast Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. James L. McKinney P.E., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision,

optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)

ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)

OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)

CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)

CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)

CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)

ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)

ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)

MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)

MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)

OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)

OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)

ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)

BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

Matt Boutell, Department of Computer Science and Software Engineering

S. Allen Broughton, Department of Mathematics

Robert M. Bunch, Department of Physics and Optical Engineering

Kurt Bryan, Department of Mathematics

Ed Doering, Department of Electrical and Computer Engineering

David L. Finn, Department of Mathematics

Charles Joenathan, Department of Physics and Optical Engineering

Cary Laxer, Department of Computer Science and Software Engineering

Michael F. McNerney, Department of Physics and Optical Engineering

J.P. Mellor, Department of Computer Science and Software Engineering

Xiaoyan Mu, Department of Electrical and Computer Engineering
Wayne T. Padgett, Department of Electrical and Computer Engineering
Deborah Walter, Department of Electrical and Computer Engineering
Huihui Xu, Department of Applied Biology and Biomedical Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (Professors McInerney, Siahmakoun, Wagner, and Syed). Students taking solid state/material science minor cannot take this certificate.

Required Courses

- 1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
- 2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
- 3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
or:
CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
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- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
SV171 Principles of Psychology
EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering management. Courses not included in this list may be approved by the Management Studies Advisor:
CE303 Engineering Economy
SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
MAXXX Any statistics courses
EMGTXXX Any engineering management course

GERMAN TECHNICAL TRANSLATOR'S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. A student must complete all the technical courses required by one of the Institute's degree-granting programs.
2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
2. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics and mechatronics. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman.

Students earning the minor must satisfy three requirements. (1) They must major in one of the following areas: Mechanical Engineering, Electrical Engineering, Computer Engineering, Computer Science, or Software Engineering to obtain depth. (2) They must complete one of the 28-credit tracks ([PDF of curriculum tracks](#)) to obtain breadth in a second area. (3) They must work on a multidisciplinary robotics senior design project by taking ROBO 410, ROBO 420, and ROBO 430. Exceptions to the robotics minor requirements require approval of the appropriate robotics advisor (below).

Students wanting to pursue the minor should complete a declaration-of-intent form and submit it to the appropriate track advisor. Completion of the program will be noted on the student's official transcript but not on the diploma. The advisors are Dr. Matthew Boutell (CSSE tracks), Dr. Carlotta Berry (ECE tracks), and Dr. David Fisher (ME tracks).

Additional information about the minor can be found at <http://robotics.rose-hulman.edu>



Institute of Technology
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Course Catalog 2010-2011

- [Programs of Study](#)
[Course Descriptions](#)
[Minors](#)
- [Special Programs](#)
[Advanced Placement](#)
[Graduate Studies](#)

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV
BIOLOGY	4	Score 4=AB101; Score 5=AB110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV151 (SV if granted SV151 for other econ exam)
ECON - MIC	4	SV151 (SV if granted SV151 for other econ exam)
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA
ENVIRONMENTAL SCIENCE	0	NONE
EUROPEAN HISTORY	4	GS
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs);

Score 5=GE 111, GE 112, & GE 113 (12cr hrs)

GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B	0	NONE
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	no credit
STUDIO ART:3D DESIGN	4	no credit
US HISTORY	4	SV
WORLD HISTORY	4	GS223

TRANSFER STUDENTS

A student transferring from another college or university is required to be in “good academic standing.” Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval in advance from the head of the department concerned.





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Offices and Services

Course Catalog 2009-2010

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Programs of Study

Programs of study leading to a Bachelor of Science degree are available in the following areas:

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics





Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering



FRESHMAN YEAR

For all curricula the following courses are required in the freshman year:

			Credits
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
HSS	XXX	Elective*	4
MA	111	Calculus I**	5
MA	112	Calculus II**	5
MA	113	Calculus III**	5

*Humanities and Social Science courses are denoted by the prefixes RH, GS, IA, SV, GE, JP, and SP.

**Students qualified for advanced placement in mathematics may be given credit by examination for one or more of these courses. The requirement for MA 111 may be fulfilled by MA 101 and 102 in certain cases.

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

Note that throughout the curricula courses in the humanities and social sciences are required of all students. Each student is encouraged to take additional non-technical courses as electives.

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[Incoming Freshman](#)

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Minors

TECHNICAL MINORS

- Applied Biology
- Astronomy
- Biochemical Engineering
- Biochemistry and Molecular Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Computational Science
- Computer Engineering
- Computer Science
- Electrical Engineering
- Entrepreneurship Minor
- Environmental Engineering
- Mathematics
- Mechanical Engineering (Thermal Fluids)
- Optical Engineering
- Physics
- Software Engineering
- Solid State Physics/Materials Science
- Statistics



HUMANITIES AND SOCIAL SCIENCES MINORS

- Anthropology
- Art
- East Asian Studies
- Economics
- European Studies
- Geography
- German
- History
- Japanese
- Language and Literature
- Latin American Studies
- Music
- Philosophy and Religion
- Political Science
- Psychology
- Spanish



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[Incoming Freshman](#)

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[Alumni and Friends](#)
[Community Members](#)

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[Parents](#)

[Intranet](#) | [Contact Us](#) | [Banner Web](#) | [Map and Directions](#) | [Employment](#) | [Accessibility](#)

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Course Catalog 2009-2010

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Special Programs

<u>Fast Track Calculus</u>	<u>Multidisciplinary Minor in Imaging</u>
<u>Fast Physics</u>	<u>Certificate In Semiconductor Materials And Devices</u>
<u>New Student Orientation</u>	<u>The Management Studies Program</u>
<u>Consulting Engineering Program</u>	<u>German Technical Translator's Certificate Program</u>
<u>Foreign Studies Program</u>	<u>Multidisciplinary Minor in Robotics</u>

FAST TRACK CALCULUS

Integral and multivariable calculus, is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and studied a year of calculus during high school. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 Math Score or 680 math/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Track Calculus satisfy Rose-Hulman's freshman Calculus requirement, are awarded 15 quarter hours of credit toward graduation, and begin their college careers as "mathematical sophomores."

Admission to Fast Track Calculus is competitive. Interested students should contact the Head of the Mathematics Department or Director of Fast Track Calculus.

FAST PHYSICS

An integrated calculus and physics course is offered during the summer (late July through late August) for selected members of our entering freshman class who have demonstrated outstanding ability in mathematics and physics having taken a year of college level calculus during high school and one year of high school physics. Participants are expected to have scored at least 700 on the mathematics portion of the SAT or 31 on the mathematics portion of the ACT. Students, who have a 700 mathematics score or 680 mathematics/700 critical reading or better on the SAT, or a 30 mathematics score and at least a 31 English score on the ACT have also been admitted to the program. Participants who successfully complete Fast Physics Program will earn credit for MA113, PH111, and PH112. Selected students are expected to have the ability to place out of MA111 and MA112, so will start in the Fall quarter having credit for MA111, MA112, MA113, PH111, PH112 – effectively as sophomores. Admission to Fast Physics is competitive. Interested students should contact the Directors of the Fast Physics Program.

NEW STUDENT ORIENTATION

To aid entering students in their adjustment to college life, a five-day orientation period for students precedes regular classroom instruction prior to the start of the academic year. Each freshman is required to be present for this program. The program offers a number of advantages to both the students and faculty. The students become acquainted with the facilities and surroundings, with each other, and with the regulations and routines of college life. Students learn about the various student organizations, opportunities for co-curricular activities and Rose-Hulman student traditions.

Further, students are introduced to the nature of science and engineering studies, and they meet with their faculty advisers and resident assistants. Talks and discussions offer them insight into the kinds of work engineers and scientists do and into the satisfactions to be derived from a career in science and engineering.

The orientation period also permits the faculty an opportunity to administer a number of diagnostic tests. These tests seek to determine achievement levels in academic areas and are useful for two purposes: they are tools to be used by the faculty advisers and counselors to do effective counseling, and they help to identify students who may need special attention.

Although Rose-Hulman uses the best available criteria to select its students, the undeniable fact is that students come to college with widely varying degrees of motivation and with widely differing qualities of high school preparation. The diagnostic efforts of the orientation period help to identify those students who could immediately qualify for advanced work in certain areas, and those who indicate a need for additional help. Students at Rose-Hulman normally complete their degree requirements in four years, but the Institute also wishes to provide for those students who, with encouragement and opportunity, do more than the normal student in four years and for those who may need special help or a slower pace of study.

CONSULTING ENGINEERING PROGRAM

Through the generosity of J. B. Wilson, a prominent consulting engineer of Indianapolis, a program was established in 1973 to emphasize career opportunities in the field of consulting engineering and to provide selected courses which would be beneficial to students interested in consulting engineering careers.

Listed below is a program guide of recommended courses for a student interested in consulting engineering. This is not a degree program but is a supplement to the normal engineering degree programs. Some of the courses are in addition to the normal engineering degree programs and may result in a student earning more credits than are required for the B.S. degree in a specific discipline.

Students desirous of pursuing the Consulting Engineering Program should enroll in the Program by filing a declaration-of-intent form with the Chairman of the Commission. In order to be certified as having completed the Program, a student is required to successfully complete the prescribed list of courses, complete the requirements for a degree in Engineering, and take the Fundamentals of Engineering examination prior to graduation.

Upon completion of the program, students will receive a Certificate of Completion at the time of their graduation from Rose-Hulman Institute of Technology. Completion of the program will be noted on the student's official transcript but not on the diploma. The Consulting Engineer Program advisor is Dr. James L. McKinney P.E., Department of Civil Engineering.

	Credit
EM104 Graphical Communications	2
RH330 Technical Communications	4
Or	
IA230 Fundamentals of Public Speaking	4
SV351 Managerial Economics	4
Or	
IA453 The Entrepreneur	4
CE303 Engineering Economy	4
Or	
CHE416 Design I: Process Economics and Equipment Design	4
EMGT552 Business Law for Technical Managers	4
CE420/CHE420/ECE466 or ME420 Consulting Engineering Seminar	2
Engineering Design (any senior Engineering design course)	4
Total	24

Exceptions to these program course requirements require approval by the Consulting Engineering Program Advisor.

Registration for & sitting for the Fundamentals of Engineering Exam required.

FOREIGN STUDIES PROGRAM

The Foreign Studies Program is an honors program that helps particularly mature and academically talented juniors to study engineering and science at selected foreign colleges and universities. Spending a quarter, a semester, or even a year at a famous overseas university, in a city steeped in visual reminders of its history, will challenge the student both academically and personally. If students demonstrate in their first two years at Rose-Hulman that they have the academic and personal maturity to handle the conflict between study and distraction, Rose-Hulman will recommend them for admission and, if not otherwise restricted, permit them to use their scholarship funds abroad.

Sophomores who have a cumulative grade point average of 3.2 or better and have an interest in the program should make a formal application to the director/advisor of the respective program by December 1 of their sophomore year. The application must contain: (a) A plan of study that has been worked out with the guidance and approval of the Professor-in-Charge of the student's discipline, the appropriate department head, and the student's adviser; and (b) two letters of recommendation from faculty members who have knowledge of the student's ability and potential for success in foreign study. If the student plans to study at a non-English speaking institution abroad (in Germany, for example) the student must also demonstrate speaking, reading, and writing ability in the language of the country. Ordinarily the student may demonstrate this by completing the equivalent of at least two years of a foreign language at the college level. Students who want to participate in the Junior year program in Germany either at the University of Stuttgart or Magdeburg must first consult with the appropriate German faculty member who will assist in the selection of the courses to be taken overseas. The same applies for intensive German language courses taken in Germany and internships in Germany.

MULTIDISCIPLINARY MINOR IN IMAGING

Imaging concerns the collection, manipulation, analysis, generation, understanding and processing of images. It includes computer graphics, computer vision, optical imaging and filtering, signal processing and aspects of artificial intelligence. Rose-Hulman Institute of Technology offers a multidisciplinary minor in imaging. Hands-

on experience is emphasized in the Imaging Systems Laboratory, which is used for project work by imaging students and graduate students whose theses involve imaging.

The minor recognizes undergraduate students who have gained a grounding in imaging systems while at Rose-Hulman. The minor requires 6 courses (at least 22 credits). Three courses are required core courses, two are electives, and one is the imaging systems project. A student would expect to take these courses starting in the junior year. A student in any major should be able to obtain an imaging minor with minimal, if any, course overload. Students interested in pursuing the minor should see the certificate advisor (listed below).

Required Courses

CSSE351 - Computer Graphics, Prerequisites: CSSE220, or CSSE221, and MA212 (Fall)

ECE480/PH437 - Introduction to Image Processing, Prerequisites: MA212, Junior standing (Winter)

OE295 - Optical Systems, Prerequisites: PH113, MA211 (Spring)

Elective Courses (choose 2 that are not named courses required for your major)

CSSE325/MA325 - Fractals and Chaotic Dynamical Systems, Prerequisites: MA212, and CSSE220 or CSSE221 (Spring)

CSSE451 - Advanced Computer Graphics, Prerequisites: CSSE351 (Winter)

CSSE461 - Computer Vision, Prerequisites: MA212, CSSE220 or CSSE221(Spring)

CSSE463 – Image Recognition, Prerequisites MA212, Junior Standing, Programming Experience (Winter)

ECE580 - Digital Signal Processing, Prerequisites: ECE380 or consent (Winter)

ECE582/PH537 - Advanced Image Processing, Prerequisites: CSSE 220 or CSSE221 or ME 323 or ECE 380 or consent; MA 212 (Spring)

MA323 - Geometric Modeling, Prerequisites: MA113 (Winter)

MA439 - Mathematical Methods of Image Processing, Prerequisites: MA212 (Fall)

OE480 - Lens Design and Aberrations, Prerequisites: OE 280 or SR/GR standing or consent of instructor (Fall)

OE592 - Fourier Optics and Applications, Prerequisites: SR/GR standing or consent of instructor (Fall)

ECE497 - Medical Imaging Systems, Prerequisites: ECE300 (Spring)

BE491 - Biomedical Imaging, Prerequisites: SR/GR standing or consent of instructor (Fall)

Other courses and independent studies which are consistent with an individual's imaging systems studies may also be used to satisfy the elective course requirements, subject to approval by the imaging systems faculty.

Imaging Project

A project with a significant imaging component is required. This may be done in any discipline. Projects must be approved by the Imaging Faculty. Projects must include both a written report and a public presentation, and be made available for future use. Students may meet this requirement in three ways: (1) A student may complete a 4-credit independent study, approved by the Imaging Faculty. (2) A student may begin the project in a course and then extend and document the project and make a public presentation during an independent study approved by the Imaging Faculty. (3) A student may complete an approved senior thesis or project involving imaging and substitute a senior thesis or project course for the independent study.

Imaging Systems Program Director

J.P. Mellor, Department of Computer Science and Software Engineering

Imaging Systems Faculty

Matt Boutell, Department of Computer Science and Software Engineering

S. Allen Broughton, Department of Mathematics

Robert M. Bunch, Department of Physics and Optical Engineering

Kurt Bryan, Department of Mathematics

Ed Doering, Department of Electrical and Computer Engineering

David L. Finn, Department of Mathematics

Charles Joenathan, Department of Physics and Optical Engineering

Cary Laxer, Department of Computer Science and Software Engineering

Michael F. McNerney, Department of Physics and Optical Engineering

J.P. Mellor, Department of Computer Science and Software Engineering

Xiaoyan Mu, Department of Electrical and Computer Engineering

Wayne T. Padgett, Department of Electrical and Computer Engineering
Deborah Walter, Department of Electrical and Computer Engineering
Huihui Xu, Department of Applied Biology and Biomedical Engineering

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should see a PHOE certificate advisor (Professors McInerney, Siahmakoun, Wagner, and Syed). Students taking solid state/material science minor cannot take this certificate.

Required Courses

- 1. PH405 Semiconductor Materials and Applications -- 3R-3L-4C F Pre: PH113 or PH255 or PH265 or consent of instructor.
- 2. EP406 Semiconductor Devices and Fabrication -- 3R-3L-4C W Pre: PH405 or consent of instructor.
- 3. EP410 Intro to MEMS: Fabrication and Applications -- 3R-3L-4C S Pre: JR or SR standing or consent of the instructor.
or:
CHE440 Process Control 4R-0L-4C W Pre: CHE202

Electives

Course	Hours	Course Title
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-Optics and Applications
PH 330	4	Material Failure
PH 401	4	Introduction to Quantum Mechanics
PH 440	4	X-rays and Crystalline Materials
EP 408	4	Microsensors
EP 411	4	Advanced Topics in MEMS
ECE 351	4	Analog Electronics
ECE 551	4	Digital Integrated Circuit Design
ECE 552	4	Analog Integrated Circuit Design
ME 302	4	Heat Transfer
ME 328	4	Materials Engineering
ME 424	4	Composite Materials & Mechanics
ME 415	4	Corrosion and Engineering Materials
CHE 314	4	Heat Transfer
CHE 315	4	Material Science and Engineering
CHE 440	4	Process Control
CHE 441	4	Polymer Engineering
CHEM 441	4	Inorganic Chemistry I
CHEM 451	4	Organic Structure Determination
CHEM 457	4	Synthetic Polymer Chemistry
CHEM 462	4	Physical Polymer Chemistry
MA 381	4	Intro to Probability with Applications to Statistics
MA 385	4	Quality Methods
MA 487	4	Design of Experiments

Overall aim of the Certificate

A certificate holder will understand how semiconductor devices work, have practical experience in the main stages of device production, have practical experience in the more common forms of device testing and characterization, and have broad understanding of the mechanical and chemical properties of the material used.

A Certificate holder will be well suited for jobs requiring an understanding of semiconductor devices and their production. These jobs include not only those directly related to device fabrication, but also those involved with testing and trouble-shooting electronic equipment and the design of machines that contain electronic equipment. The experience in simple device fabrication that the Certificate provides is particularly useful for future engineers in “process” industries.

THE MANAGEMENT STUDIES PROGRAM

The Management Studies Program is a selected group of courses which develops a broad understanding of management in business and society. Like the Rose-Hulman Technical Translators Program, the Management Studies Certificate is a supplement to an engineering or science degree. The curriculum is a core of required courses in ethics, engineering management, economics, and technical communication with electives dealing with the role of management in society and specific tools for managers.

Statement of Objectives

The Management Studies Program broadens the education of engineers and scientists through a curriculum which:

- teaches the quantitative and economic concepts needed in management decision-making;
- promotes productivity through people;
- stresses communication skills required in management;
- examines intended and unintended impacts of management decisions;
- explores the social, legal, and ethical contexts of management.

Although the nine courses necessary to receive the certificate are a challenging addition to the undergraduate's academic load, many of them may simultaneously be used to fulfill Humanities and Social Science, technical elective, and other degree requirements. Science majors should be able to complete the program easily within the regular four year pattern, but engineering majors may have to overload. In order to minimize conflicts and meet individual needs, each student will design a specific program with the Management Studies Adviser in the first quarter of the sophomore year.

Requirements:

1. All of the following core Courses:
SV151 Principles of Economics
SV303 Business and Engineering Ethics
RH330 Technical and Professional Communication
SV350 Managerial Accounting or SV356 Corporate Finance
SV351 Managerial Economics
2. Two of the following Management in Society Courses (in addition to the core courses):
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EMGTXXX Engineering Management
SV304 Bioethics
EMGT533 Intercultural Communication
GS432 Literature and Film of the Global Economy
SV353 Industrial Organization
SV357 Labor Economics
IA352 Game Theory
SV463 Seminar on America's Future
IA453 The Entrepreneur
EMGT526 Technology Management and Forecasting
3. Two courses from the following list. The student may choose to emphasize a strength area such as quantitative analysis, economics, or engineering management. Courses not included in this list may be approved by the Management Studies Advisor:
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SV353 Industrial Organization
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
GS350 International Trade: Globalization
GS351 International Finance
CE441 Construction Engineering
CE442 Cost Engineering
MA444 Deterministic Models in Operations Research
MA445 Stochastic Models in Operations Research
CSSEXXX Courses beyond CSSE 120 in Computer Science
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Certificate Requirements

A student must have a 3.0 in the first two years of the foreign language and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. *A student must complete all the technical courses required by one of the Institute's degree-granting programs.*

- 2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413). See the Humanities and Social Sciences (HSS) section of this catalogue for a description of these courses.
- 3. A student who successfully completes the requirements for the German Technical Translator Certificate is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- 1. A student who is in the German Studies Program in Culture and Technology is not required to take RH131, Rhetoric and Composition.
- 2. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60

MULTIDISCIPLINARY MINOR IN ROBOTICS

Robotics is a fast-growing field that is inherently multidisciplinary, incorporating mechanical systems, electrical systems, and software. It includes mobile robotics and mechatronics. Rose-Hulman Institute of Technology offers a multidisciplinary minor in robotics to recognize students who have gained experience in these areas while at Rose-Hulman.

Students earning the minor must satisfy three requirements. (1) They must major in one of the following areas: Mechanical Engineering, Electrical Engineering, Computer Engineering, Computer Science, or Software Engineering to obtain depth. (2) They must complete one of the 28-credit tracks to obtain breadth in a second area. (3) They must work on a multidisciplinary robotics senior design project by taking ROBO 410, ROBO 420, and ROBO 430. Exceptions to the robotics minor requirements require approval of the appropriate robotics advisor (below).

Students wanting to pursue the minor should complete a declaration-of-intent form and submit it to the appropriate track advisor. Completion of the program will be noted on the student's official transcript but not on the diploma. The advisors are Dr. Matthew Boutell (CSSE tracks), Dr. Carlotta Berry (ECE tracks), and Dr. David Fisher (ME tracks).

Additional information about the minor can be found at <http://robotics.rose-hulman.edu>



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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Catalog 2009-2010

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Advanced Placement

ADVANCED PLACEMENT

During Freshman Orientation, students are given the opportunity to qualify for credit by exam in a selected number of courses. Other exams may be given by making arrangements with the appropriate department head. Students may also qualify for advanced placement through the Advanced Placement Examinations of the College Board. The required score and corresponding course at Rose-Hulman are listed below.

AP Score of 4 or 5	RHIT Credit Hours	RHIT Equivalent
ART HISTORY	4	SV
BIOLOGY	4	Score 4=AB101; Score 5=AB110
CALCULUS AB	5	MA111
CALCULUS BC	10	MA111 & MA 112
CHEMISTRY	**	Score 4=8 cr hrs for CHEM 111, 113; Score 5=12 cr hrs for CHEM 111, 113, 115
CHINESE LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
COMPUTER SCIENCE A	8	Eligible for CSSE 221. Upon successful completion of CSSE 221, student is awarded 4 credits for CSSE 120.
ECON - MAC	4	SV151 (SV if granted SV151 for other econ exam)
ECON - MIC	4	SV151 (SV if granted SV151 for other econ exam)
ENG LANG/COMP	4	RH131
ENG LIT/COMP	4	IA
ENVIRONMENTAL SCIENCE	0	NONE
EUROPEAN HISTORY	4	GS
FRENCH LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
GERMAN LANG & CULTURE	**	Score 4=GE 111 & GE 112 (8cr hrs);

Score 5=GE 111, GE 112, & GE 113 (12cr hrs)

GOV & POL COMP	4	GS161
GOV & POL US	4	SV166
HUMAN GEOGRAPHY	4	GS291
ITALIAN LANG & CULTURE	**	Score 4=8 cr hrs of foreign lang; Score 5=12 cr hrs of foreign lang
JAPANESE LANG & CULTURE	**	4=8 hours of foreign language; 5=12 hours of foreign language
LATIN - VERGIL	4	4 additional hours of foreign language
MUSIC THEORY	4	IA246
PHYSICS B	0	NONE
PHYSICS C - E&M	4	PH112
PHYSICS C - MECH	4	PH111
PSYCHOLOGY	4	SV171
SPANISH LANG & CULTURE	**	Score 4=SP 111 & SP 112 (8cr hrs); Score 5=SP 111, SP 112, & SP 113 (12 cr hrs)
SPANISH LIT	4	4 additional hours of foreign language
STATISTICS	4	MA223
STUDIO ART: DRAWING	4	IA142
STUDIO ART:2D DESIGN	4	no credit
STUDIO ART:3D DESIGN	4	no credit
US HISTORY	4	SV
WORLD HISTORY	4	GS223

TRANSFER STUDENTS

A student transferring from another college or university is required to be in “good academic standing.” Credit may be given at Rose-Hulman for work done elsewhere which is considered to be equivalent of the corresponding course at Rose-Hulman if a grade of C or better was earned.

Credits earned elsewhere will be evaluated by the head of the department in which the courses would be taught at Rose-Hulman. Final acceptance of the credit is at the discretion of the head of the department in which the student is seeking a degree.

Students enrolled at Rose-Hulman who plan to take courses at another institution with the intention of transferring the credit to Rose-Hulman should obtain approval in advance from the head of the department concerned.



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Spring Term		Credit
BIO 230	Eukaryotic Cell & Molecular Biology	4
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
PH 113	Physics III	4
MA 223	Engineering Statistics	4
Total		16

Junior Year

Fall Term		Credit
BIO 320	Ecology	4
CHEM 330	Biochemisty	4
HSS	Elective	4
BIO 399	Practice of Science	4
Total		16

Senior Year

Fall Term		Credit
BIO 498	Senior Thesis Research III	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16

Winter Term		Credit
BIO 330	Evolutionary Biology	4
BIO 496	Senior Thesis Research I	2
BIO	Elective	4
HSS	Elective	4
Total		14

Winter Term		Credit
BIO 499	Senior Thesis Research IV	2
	Science/Technical Elective	4
BIO	Elective	4
HSS	Elective	4
Total		14

Spring Term		Credit
BIO 310	Plant Structure & Function	4
BIO 497	Senior Thesis Research II	4
SV 304	Bioethics	4
HSS	Elective	4
Total		16

Spring Term		Credit
BIO	Elective	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16
Total credits required:		188

A BIO science/technical elective is any Rose-Hulman course that has a prefix of BE, BIO, BMTH, CE, CHE, CHEM, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required BIO courses	52 credits
BIO electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	12 credits
Required MA, CHEM, PH	63 credits
Required CLSK	1 credit
Sci/Tech electives	12 credits
Required BE course	4 credits
Total	188 credits

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology

requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required Courses

Elective Courses

Choose 12 credits* from the following courses:

Course	Description	Hours
CHEM 111, 113, 115	General Chemistry	12
CHEM 251, 252, 253	Organic Chemistry	9
CHEM 251L, 252L, 253L	Organic Chemistry Lab	3
CHEM 330, 430, 433	Biochemistry	9
CHEM 361, 362 or CHEM 360 and		
CHE 303, 304	Physical Chemistry	8
BIO 110, 120, 130	Biology	12
BIO 210	Genetics	4
BIO 220, 230	Molecular Biology	8
BIO 411	Genetic Engineering	4
Total		69

Course	Description
BIO 330	Evolutionary Biology
BIO 421	Microbiology
BIO 431	Genomics and Proteomics
BIO 441	Virology
BIO 451	Cancer Biology
BIO 492	Directed Study in Biology
CHEM 225	Analytical Chemistry
CHEM 291	Introduction to Research
CHEM 331	Biochemistry II
CHEM 431	Biochemical Instrumentation
CHEM 451	Organic Structure Determination
CHEM 290 or	
CHEM 490	Chemical Research
PH 302	Biophysics

Total Credits for Second Major 81

**Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the BIO electives listed, and 4 credits chosen from any BIO or BE course.*

STUDENTS WITH A MAJOR IN BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above BIO course (total: 29 hours required beyond Biology major).

Biology Minor

Biology is an exciting subject that has applications relevant to all other fields of study at the Institute. Students who are interested in enriching their major area of study with a knowledge of life sciences can do so with the Biology Minor. With proper course selection, the Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Minor in Biology has the following requirements.

1. All students must complete BIO110 (Cell Structure and Function) or BIO130 (Evolution and Diversity) and four more courses in biology (BIO) or allied areas, above those courses already specifically required to fulfill the student's major, subject to the following requirements:
 - a. At least three of the four electives must be BIO courses.
 - b. At least three of the electives must be 200-level or above.
2. Students electing to pursue the minor in Biology must follow a plan of study that is approved by the Minor Advisor. Current advisor information and a form for the planning and approval of a minor can be obtained from the BBE Department Secretary.
3. Allied area courses could include:

BE310	Analysis of Physiological Systems I	IA236	Communicating STEM to a Public Audience
BE320	Analysis of Physiological Systems II	IA239	Rhetoric of Science
BE570	Intro to Tissue Engineering	IA401	Philosophy of Science
BMTH310	Mathematical Biology	IA471	Computational Psychology
BMTH311	Systems Biology	MA482/BE482	Bioengineering Statistics
BMTH312	Bioinformatics	ME447	Visualizing Data
BMTH413	Computational Biology	PH302	Biophysics
CE460	Intro to Environmental Engineering	SV304	Bioethics
CHE545	Intro to Biochemical Engineering	SV371	Social Psychology
CHEM264	Intro to Environmental Science	SV373	Abnormal Psychology
CHEM330	Biochemistry	SV472	Studying Human Behavior
CHEM430	Advanced Biochemistry	SV386	Human Evolution

Additional courses not listed here can be considered on a case-by-case basis.

Biochemistry & Molecular Biology Minor

Completion of BIO110, CHEM111, CHEM113 and CHEM115. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

Course	Description
BIO 210	Mendelian and Molecular Genetics
BIO 220	Prokaryotic Cell and Molecular Biology
or	
BIO 230	Eukaryotic Cell and Molecular Biology
BIO 411	Genetic Engineering
or	
BIO 431	Genomics and Proteomics
CHEM 230	Introduction to Organic Chemistry and Biochemistry
or	
CHEM 251	Organic Chemistry I
and	
CHEM 252	Organic Chemistry II
CHEM 330	Biochemistry
CHEM 430	Advanced Biochemistry
with	
CHEM 433	Biochemistry Laboratory

Biology is an exciting subject that has applications relevant to all other fields of study at the Institute. Students who are interested in enriching their major area of study with a knowledge of life sciences can do so with the

Biology Minor. With proper course selection, the Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

BIOCHEMISTRY PLAN OF STUDY

Freshman Year

Fall Term		Credit
CHEM 111*	General Chemistry I	4
MA 111	Calculus I	5
BIO 110	Cell Structure & Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		18

Winter Term		Credit
CHEM 113*	General Chemistry II	4
MA 112	Calculus II	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		17

Spring Term		Credit
CHEM 115	General Chemistry III	4
MA 113	Calculus III	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
PH 113	Physics III	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
BIO 210	Mendelian & Molecular Genetics	4
Total		16

Winter Term		Credit
CHEM 200	Career Preparation	1
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
CHEM 291	Intro to Undergraduate Research	4
MA 381	Introduction to Probability with Applications to Statistics	4
BIO 220	Prokaryotic Cell & Molecular Biology	4
Total		16

Spring Term		Credit
CHEM 253	Organic Chemistry III	3

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

CHEM 253L	Organic Chemistry III Lab	1
CHEM 225	Analytical Chemistry	4
BIO 230	Eukaryotic Cell & Mol. Biology	4
RH 330 (or HSS)	Technical Communication	4
Total		16

Junior Year

Fall Term		Credit
CHEM 326	Bioanalytical Chemistry	4
CHEM 330	Biochemistry I	4
CHEM 361	**Physical Chemistry I	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 395	Chemistry Seminar	0
CHEM 490	Research	1
HSS (or RH330)	Elective	4
Total		17 or 18

Winter Term		Credit
CHEM 327	Advanced Analytical	4
CHEM 362	**Physical Chemistry II	4
CHEM 331	Biochemistry II	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

Spring Term		Credit
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 430	Advanced Biochemistry	4
CHEM 433	Biochemistry Lab	1
HSS	Elective	4
CHEM 490	Research	1
Total		14 or 15

Senior Year

Fall Term		Credit
CHEM 441	Inorganic Chemistry I	4
CHEM 495	Chemistry Seminar	0
CHEM 490	Chemistry Research	1
CHEM 491	Research Thesis (F, W or S)	1
##Advanced Chemistry or Biochemistry Elective		4
Advanced Biology Elective		4
Free Elective		4
Total		17 or 18

Winter Term		Credit
CHEM 496	Chemistry Seminar	0
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
##Advanced Biology, Chemistry, Biochemistry Elective		4
Free Elective		4
Total		12, 13, or 14

Spring Term		Credit
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Free Elective		4
Free Elective		4
Total		12, 13, or 14
Total credits required:		192

Notes: Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441	4
Biochemistry	330, 331, 430, 433	13
Research	291, 490	8
Chemical Communication	400, 401, 402, 403	4
Career Preparation	200	1
Electives		8
Total		86

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total
Chemistry	78	8	86
Physics	12	0	12
Mathematics	23	0	23
Biology	20	0	20
Humanities and Social Sciences	4	32	36
Electives	0	16	16
College and Life Skills	1	0	1
Total	136	56	194

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM111	General Chemistry I	4
CHEM113	General Chemistry II	4
CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		32

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	
or CHEM253	Organic Chemistry III	4
CHEM330	Biochemistry I	
or CHEM361	Physical Chemistry I	4
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24

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Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Biomathematics

MISSION STATEMENT

An increasing number of problems in the biological sciences are being solved using sophisticated mathematical and computational tools. The biomathematics degree blends mathematics, biology, and computer science in preparation for continued graduate studies and for careers in the quantitative life sciences. The degree's mission is to provide a world class undergraduate education in applied mathematics used in support of the life sciences.

The degree's mission is supported and motivated by these facts:

- Biological data is being generated with unprecedented precision and in unfathomable volumes.
- Quantifying biological observations requires mathematical and statistical analysis.

The basic principles of complex biological systems support mathematical and computational modeling, which can lead to testable hypotheses and new discoveries.

PROGRAM GOALS AND OBJECTIVES

The biomathematics degree will provide a broad based undergraduate experience that 1) prepares students with a rigorous education in applied mathematics, 2) educates students in the fundamental principles of biology, 3) trains students to work in a computational arena, 4) introduces students to several of the sister disciplines of computational biology, mathematical biology, bioinformatics, systems biology, and biostatistics, and 5) guides students through an advanced undergraduate research project. The degree will also liberally educate students through the study of the humanities and social sciences. Students of the program will be encouraged to participate in external and internal research programs and industrial internships and/or co-ops.

PROGRAM OUTCOMES

Graduates will be prepared for graduate study in any of the sister fields as well as for careers in the quantitative life sciences. Each graduate will complete a capstone research experience that will culminate in a written report and a public presentation.

BIOMATHEMATICS PLAN OF STUDY

Freshman Year

Fall Term		Credit
BIO 110	Cell Structure and Function	4
CHEM 111	General Chemistry	4
MA 111	Calculus I	5
RH 131	Rhetoric and Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term		Credit
PH 111	Physics I	4
CHEM 113	General Chemistry II	4
MA 112	Calculus II	5
HSS		4

Sophomore Year

Fall Term		Credit
BIO 210	Mendelian & Molecular Genetics	4
MA 211	Differential Equations	4
CSSE 120	Intro. to Software Devel.	4
PH 113 or CHEM 251	Add'l Science	4
Total		16

Winter Term		Credit
BIO 220	Microbiology	4
MA 212	Matrix Algebra & Systems of D.E.	4

Biography
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

Total		17
<i>Spring Term</i>		<i>Credit</i>
BIO 130	Evolution and Diversity	4
PH 112	Physics II	4
MA 113	Calculus III	5
HSS		4
Total		17

MA 381	Intro. to Probability	4
HSS		4
MA 200	Career Preparation	1
Total		17
<i>Spring Term</i>		<i>Credit</i>
BIO 230	Cell Biology	4
MA 371	Linear Algebra	4
HSS		4
Elective*		4
Total		16

Junior Year

<i>Fall Term</i>		<i>Credit</i>
BMTH 310	Mathematical Biology	4
MA 382	Intro. to Statistics w/Prob	4
HSS		4
Elective*		4
Total		16

<i>Winter Term</i>		<i>Credit</i>
BMTH 311	Systems Biology	4
MA 332	Intro to Computational Sci.	2
RH 330	Technical & Profess. Comm.	4
Elective*		4
Total		16

<i>Spring Term</i>		<i>Credit</i>
BMTH 312	Bioinformatics	4
HSS		4
Elective*		4
Elective*		4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
BMTH 496	Capstone Experience I	2
HSS		4
Elective*		4
Elective*		4
Total		14

<i>Winter Term</i>		<i>Credit</i>
BMTH 497	Capstone Experience II	4
Elective*		4
Elective*		4
Elective*		4
Total		16

<i>Spring Term</i>		<i>Credit</i>
BMTH 413	Computational Biology	4
BMTH 498	Capstone Experience III	2
Elective*		4
Elective*		4
Total		14
Total credits required:		193

- *Requirements: 3 Free Electives 12 hours
- 3 MA Electives 12 hours
- 5 Tech Electives 20 hours
- 1 Domain Elective 4 hours

SUMMARY OF GRADUATION REQUIREMENTS

HSS		36 hours
CLSK	CLSK 100	1 hour
Math Core	MA 111, 112, 113, 200, 211, 212, 332, 371 or 373, 381, and 223 or 382	40 hours
Biomath Core	Four BMTH courses numbered 300 or above	16 hours
Basic Science	BIO 110, 130, 120 or 210, 220, and 230 CHEM 111, 113 PH 111, 112 one of CHEM 251 or PH 113	40 hours
Computer Science	CSSE 120	4 hours
Capstone Experience	BMTH 496, 497, 498	8 hours
Domain Elective	Any of the following, with no course substitutions permitted.	4 hours

BIO 330 Evolutionary Biology 4R-0L-4C W Prereq. BIO 130
CHEM 330 Biochemistry I 4R-0L-4C W Prereq. CHEM 252
CSSE 304 Programming Language Concepts 4R-0L-4C W Prereq. CSSE
230 and MA 275
MA 366 Functions of a Real Variable 4R-0L-4C W Prereq. MA 275 and MA
113

Math Electives	Any mathematics course numbered 300 or above, or MA 275	12 Hours
Technical Electives	Non-mathematics courses numbered 200 or above in the physical sciences, life sciences, computer science, or engineering	20 Hours
Free Electives		12 Hours
Total		193 hours

SECOND MAJOR IN BIOMATHEMATICS

The second major in biomathematics is open to all majors with the following requirements and restrictions.
Eligibility and limitations

- The MA/BMTH double major must be seperated by at least 24 hours.

REQUIREMENTS (72 HOURS)

Math Core	MA 211, 332, 371 or 373, 381, and 223 or 382	20 hours
Biomath Core	any four BMTH courses numbered 300 or above	16 hours
Math Electives		12 hours
Biology	BIO 110 and three courses from different categories described below BIO 130 BIO 120 or 210 BIO 205 or 230 BIO 220	16 hours
Senior Capstone Experience	BMTH 496, 497, 498	8 hours

MINOR IN BIOMATHEMATICS


A minor in biomathematics is open to all students.

REQUIREMENTS (47 HOURS)

Math Core	MA 111, 112, 113, 211, 212, and 223 or 382	27 hours
Biomath Core	any three BMTH courses numbered 300 or above	12 hours
Biology	BIO 110 and one of BIO 205, 210, 220, 230	8 hours

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biomedical Engineering

Biomedical engineers use science, engineering, and mathematics to understand and solve medical problems. We focus on improving people's quality of life. Biomedical engineers who specialize in biomechanics design and analyze biological systems or medical devices that have to do with forces, stresses, and strains. This includes studying the motions of bodies or joints, fluid flow, the deformation of tissues or materials, and the transport of molecules and chemicals through tissues and across membranes. Biomedical engineers who specialize in bioinstrumentation use electronics and signal analysis to take measurements from and deliver stimuli to living cells and tissues. Examples include cochlear implants, pacemakers, and patient monitoring equipment. Biomedical engineers who specialize in biomaterials design and study materials to replace, repair, and interact with cells and tissues in the body. Examples include metal, ceramic, polymer, or tissue-engineered implants; these implants can be permanent or biodegradable. The United States Bureau of Labor Statistics has projected that jobs for biomedical engineers will increase by 23% between the years 2014 and 2024. The biomedical engineering program at Rose-Hulman produces engineers with the medical and biological expertise needed to solve health care problems during careers in technical and health-related industries, as well as in government or industrial laboratories. Alumni wishing to continue their studies in graduate/professional school or health professions programs will be well-qualified to do so.

Biomedical Engineering Program Educational Objectives

- Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."
- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
 - Graduates will apply practical and technical skills required for biomedical engineering practice.
 - Graduates will work and communicate effectively with all of the people around them.
 - Graduates will exercise their professional responsibilities towards society.
 - Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

- By the time students graduate with an undergraduate Biomedical Engineering degree from Rose-Hulman, they will have:
- a) An ability to apply knowledge of mathematics, science, and engineering.
 - b) An ability to design and conduct experiments, as well as to analyze and interpret data.
 - c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
 - d) An ability to function on multidisciplinary teams.
 - e) An ability to identify, formulate, and solve engineering problems.
 - f) An understanding of professional and ethical responsibility.
 - g) An ability to communicate effectively.
 - h) The broad education necessary to understand the impact of engineering solutions in a global, economic,

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

- environmental, and societal context.
- i) A recognition of the need for, and an ability to engage in life-long learning.
 - j) A knowledge of contemporary issues.
 - k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit
BIO 110	Cell Structure and Function	4
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
EM 104	Graphical Communication	2
Total		16

Winter Term		Credit
BIO 120	Comparative Anatomy & Physiology	4
PH 112	Physics II	4
MA 112	Calculus II	5
EM 121	Statics and Mechanics of Materials I	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
RH 131	Rhetoric & Composition	4
MA 113	Calculus III	5
BE 100	Problem Solving in the Biological Sciences and Engineering	4
Total		17

Junior Year

Fall Term		Credit
HSS	Elective	4
BIO 205	Cellular Physiology	4
HSS or RH330	Tech & Profess'l Comm or HSS Elective	4
EM 204	Statics and Mechanics of Materials II	4
Total		16

Winter Term		Credit
BE 310	Physiological Systems I	4
BE 331	Biomechanics	3
BE 351	Biomedical Engineering Lab	2
BE 361	Biomaterials	3
HSS or RH330	HSS Elective or Tech & Profess'l Comm	4
Total		16

Sophomore Year

Fall Term		Credit
ES 201	Conservation & Accounting Principles	4
CHEM 111	General Chemistry I	4
MA 211	Differential Equations	4
ES 203	Electrical Systems	4
Total		16

Winter Term		Credit
ES 202	Fluid and Thermal Systems	3
ES 204	Mechanical Systems	3
MA 212	Matrix Algebra and Systems of Differential Equations	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		18

Spring Term		Credit
BE 201	Biomedical Measurements	4
BIO 130	Evolution and Diversity	4
ES 205	Analysis & Design of Engineering Systems	4
MA 223	Engineering Statistics	4
Total		16

Senior Year

Fall Term		Credit
BE 410	Biomedical Engineering Design I	4
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
Total		16

Winter Term		Credit
BE 420	Biomedical Engineering Design II	4
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
Total		16

Spring Term		Credit
BE 430	Biomedical Engineering Design III	2

Spring Term			HSS	Elective	4
SV 304	Bioethics	4		Free Elective	4
BE 320	Physiological Systems II	4	BE	Area Elective	4
BE 390	Principles of Biomedical Engineering Design	2		Total	14
BE	Area	4		Total credits required:	192
	Total	14			

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the BBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanics
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317	Design for Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols
BE 435/535	Biomedical Optics
BE 516	Introduction to MEMS
BE 520	Introduction to Brain-Machine Interfaces
BE 541	Medical Imaging
BE 543	Neuroprosthetics
BE 555	Electrophysiology
ECE 230	Introduction to Embedded Systems
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems

BIOMECHANICS CONCENTRATION

Course	Title
ME 317	Design for Manufacturing
BE 525	Biomedical Fluid Mechanics
BE 531	Biomechanics II
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopaedic Biomechanics
BE 550	Research Methods in Biomechanics
EM 403	Advanced Mechanics of Materials

ME 422	Finite Elements for Engineering Applications
ME 520	Computer-Aided Design and Manufacturing
ME 522	Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

- 1. Pass a minimum of 8 credit hours of BE 492.
- 2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
- 3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Minor

The biomedical engineering minor is intended to provide a biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and healthcare related fields.

In order to complete the requirements of the biomedical engineering minor, a student must complete either BIO 110-Cell Structure & Function or BIO 120-Comparative Anatomy & Physiology AND complete four courses from the list shown below. Other BE courses may be substituted with approval by the BBE Department Head. At least three of the courses must have a BE prefix.

BIO411	Genetic Engineering
BE310	Analysis of Physiological Systems I
BE320	Analysis of Physiological Systems II
BE331 and BE352	Biomechanics and Biomechanics Lab
BE340 *	Biomedical Signal Processing *
BE350 **	Biocontrol Systems **
BE361 and BE353	Biomaterials and Biomaterials Lab
BE435/535	Biomedical Optics
BE/MA482	Bioengineering Statistics
BE520	Introduction to Brain Machine Interfaces
BE525	Biomedical Fluid Mechanics
BE531	Biomechanics II
BE534	Soft Tissue Mechanics
BE539	Multiscale Biomechanics

BE543	Neuroprosthetics
BE545	Orthopaedic Biomechanics
BE560	Tissue-Biomaterial Interactions
BE570	Introduction to Tissue Engineering

* BE340 cannot be used for a BE minor by students majoring in electrical or computer engineering.

** BE350 cannot be used for a BE minor by students who have taken ECE320 or ME406.

In addition to courses in the above area concentration, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

BE201	Biomedical Instrumentation and Measurements
EM121	Statics & Mechanics of Materials I
EM204	Statics & Mechanics of Materials II
EM301	Fluid Mechanics
ECE180	Introduction to Signal Processing
ECE203 *	DC Circuits
ECE204	AC Circuits
ES201	Conservation & Accounting Principles
ES202	Fluid Systems
ES203 *	Electrical Systems
ES204	Mechanical Systems
CHE201	Conservation Principles and Balances
CHE202	Basic Chemical Process Calculations
CHE301	Fluid Mechanics

* Students may use either ECE203 or ES203 for a BE minor, but not both of these courses.

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the head of the Department of Biology and Biomedical Engineering.



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News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

- Our graduates will attain a promotion and/or responsibilities beyond their entry-level position, or progress toward the completion of an advanced degree.
- Our graduates will continue to develop professionally.
- Our graduates will collaborate professionally within or outside of their organizations at a regional, national and/or international level.
- Our graduates will participate in service to their professions and/or community organizations.

Student Outcomes

Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

11. A knowledge of contemporary issues

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4
Total		14

Winter Term		Credit
CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5
PH 111	Physics I	4
HSS	Elective	4
Total		17

Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Freshman Year (A2 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4
Total		14

Winter Term		Credit
CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5
PH 111	Physics I	4
HSS	Elective	4
Total		17

Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Sophomore Year (A1 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4
HSS	Elective	4

Sophomore Year (A2 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4
HSS	Elective	4

Total		16
Winter Term		Credit
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
Total		16

Spring Term		Credit
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
HSS	Elective	4
Total		16

Junior Year (A1 Schedule)

Fall Term		Credit
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
CHE 315	Materials Science	4
CHEM 225	Analytical Chemistry I	4
Total		16

Winter Term		Credit
CHE 321	Applications of Heat and Mass Transfer	4
CHEM 360	Intro Physical Chemistry	4
MA 223	Engineering Statistics I	4
RH 330	Technical and Professional Communication	4
Total		16

Spring Term		Credit
CHE 404	Kinetics & Reactor Design	4
CHE 411	Chemical Engineering Lab I	3
ECE 206	Elements of Electrical Engineering	4
	Elective (Free)	4
Total		15

Senior Year (A1 Schedule)

Fall Term		Credit
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4
CHE 416	Design I	4

Total		16
Winter Term		Credit
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
Total		16

Spring Term		Credit
MA 223	Engineering Statistics I	4
CHEM 225	Analytical Chemistry I	4
HSS	Elective	4
CHE 315	Materials Science	4
Total		16

Junior Year (A2 Schedule)

Fall Term		Credit
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
Total		16

Spring Term		Credit
CHE 321	Applications of Heat and Mass Transfer	4
CHE 411	Chemical Engineering Lab I	3
CHEM 360	Intro Physical Chemistry	4
	Elective (Free)	4
Total		15

Senior Year (A2 Schedule)

Fall Term		Credit
CHE 404	Kinetics & Reactor Design	4
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4

Free Elective(Free)		4	CHE 416	Design I	4
Free Elective(CHE)		4	Free Elective(Free)		4
Total		17	Total		17
Winter Term			Winter Term		
CHE 413	Chemical Eng. Lab III	4	CHE 413	Chemical Eng. Lab III	4
CHE 417	Design II	4	CHE 417	Design II	4
CHE 440	Process Control	4	CHE 440	Process Control	4
HSS	Elective	4	HSS	Elective	4
Total		16	Total		16
Spring Term		Credit	Spring Term		Credit
CHE 418	Design III	2	CHE 418	Design III	2
HSS	Elective	4	HSS	Elective	4
HSS	Elective	4	Elective(CHE)		4
Elective(Approved)		4	Elective(CHE)		4
Elective(CHE)		4	Elective(Approved)		4
Total		18	Total		18
Total credits required:		194	Total credits required:		194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 405 Introduction to MEMS: Fabrication and Applications
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 460 Particle Technology
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 515 Nanomaterials Science and Engineering
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics (including biomathematics), or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see

below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 320 Fundamentals of Heat and Mass Transfer
- CHE 321 Applications of Heat and Mass Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- BIO110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- BIO210 - Mendelian and Molecular Genetics
- BIO220 - Microbiology
- or
- BIO230 - Cell Biology
- BIO411 - Genetic Engineering
- BIO421 - Applied Microbiology
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary. Students interested in the Biochemical Engineering area minor should consult the CHE Department head and receive prior approval for any equivalent courses to be considered.

AREA OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with prior approval by the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 450 Combustion

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT562 Risk Analysis and Management
- EMGT581 Multi-objective Optimization
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include biology, chemical engineering and mathematics.

CHEMISTRY PLAN OF STUDY

Freshman Year

Fall Term		Credit
CHEM 111*	General Chemistry	4
MA 111	Calculus I	5
BIO 110**	Cell Structure and Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		18

Winter Term		Credit
CHEM 113*	General Chemistry II	4
MA 112	Calculus II	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		17

Spring Term		Credit
CHEM 115	General Chemistry III	4

Sophomore Year

Fall Term		Credit
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
PH 113	Physics III	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Free Elective	4
Total		16

Winter Term		Credit
CHEM 200	Career Preparation (take in winter or spring)	1
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
CHEM 291	Intro to Undergraduate Research	4
MA 381	Introduction to Probability with Applications to Statistics	4

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

MA 113	Calculus III	5
HSS	Elective	4
PH 112	Physics II	4
Total		17

Free Elective		4
Total		16 or 17
Spring Term		Credit
CHEM 200	Career Preparation (take in winter or spring)	1
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
CHEM 225	Analytical Chemistry I	4
HSS	RH 330	4
Free Elective		4
Total		16 or 17

Junior Year

Fall Term		Credit
CHEM 326	Bioanalytical Chemistry	4
CHEM 361	***Physical Chemistry I	4
CHEM 330	Biochemistry I	4
CHEM 391	Research Proposal (F,W or S)	1
CHEM 395	Chemistry Seminar	0
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

Winter Term		Credit
CHEM 327	Advanced Analytical	4
CHEM 362	***Physical Chemistry II	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 490	Research	1
HSS	Elective	4
Free Elective		4
Total		17 or 18

Spring Term		Credit
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 451	Organic Structure Determination	4
HSS	Elective	4
Free Elective		4
CHEM 490	Research	1
Total		17 or 18

Senior Year

Fall Term		Credit
CHEM 441	Inorganic Chemistry I	4
CHEM 490	Research	1
CHEM 491	Research Thesis (F, W or S)	1
CHEM 495	Chemistry Seminar	0
CHEM 497	Research Presentation (F, W or S)	1
Chemistry Elective		4
Free Elective		4
Total		13, 14, or 15

Winter Term		Credit
CHEM 442	Inorganic Chemistry II	4
CHEM 491	Research Thesis (F, W or S)	1
CHEM 496	Chemistry Seminar	0
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Chemistry Elective (400-level)###		4
Total		12, 13, or 14

Spring Term		Credit
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Free Elective		4
Free Elective		4
Total		12, 13, or 14
Total credits required:		191

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM 111 General Chemistry I is an automatic substitution for the former CHEM 105 Engineering Chemistry I.

CHEM 113 General Chemistry II is an automatic substitution for the former CHEM 107 Engineering Chemistry II.

*BIO 120 or BIO 130 may be substituted for BIO 110

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Summary of minimum graduation requirements:

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441, 442	4
Biochemistry	330	4
Organic Structure Determination	451	4
Chemical Communication	400, 401, 402, 403	4
Research	291, 490	8
Career Preparation	200	1
Electives		8
Total		85

Course or areas	Required	Elective	Total
Chemistry	77	8	85
Physics	12	0	12
Mathematics	23	0	23
Biology	4	0	4
Humanities and Social Sciences	4	32	36
Electives	0	32	32
College and Life Skills	1	0	1
Total	121	76	193

Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in biology or chemical engineering are different from those majoring in other disciplines.

Minor in Chemistry for Most Students

Course Number	Course Title	Credits
CHEM 113	General Chemistry II	4
CHEM 115	General Chemistry III	4
CHEM 225	Analytical Chemistry	4
CHEM 251	Organic Chemistry I	4
CHEM 252	Organic Chemistry II	4
*Approved List of		4

Chemistry Electives

Total	24
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*Approved list of chemistry electives include CHEM 253, CHEM 290 (up to two credit hours), CHEM 291, or any 300 or 400 level chemistry courses.

Minor in Chemistry for Chemical Engineering and Biology Majors

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student’s major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.



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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society’s need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department’s Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department’s Program Educational Objectives and Student Learning Outcomes*

Program Educational Objectives

- I. Graduates will demonstrate the ability to perform **essential engineering functions** in the design, management, or construction industry.
- II. Graduates will demonstrate the ability to **design/construct complex engineering systems** in the broad-based engineering industry.
- III. Graduates will demonstrate their potential for **technical leadership and management**.

Student Learning Outcomes

1. **Technical Core** - Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
2. **Experiments** - Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.
3. **Engineering Problems** - Develop problem statements and solve well-defined engineering problems in

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

four technical areas appropriate to civil engineering.

- 4. **Engineering Impact** - Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- 5. **Contemporary Issues** - Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.
- 6. **Design** - Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- 7. **Multidisciplinary** - Function effectively as a member of a multidisciplinary team.
- 8. **Professional/Ethical** - Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- 9. **Communication** - Organize and deliver effective verbal, written, and graphical communications.
- 10. **Engineering Tools** - Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.
- 11. **Life Long Learning** - Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- 12. **Leadership** - Apply leadership principles to direct the efforts of a small group.
- 13. **Service** - Use one's time and skills to benefit an individual or community without cost to the recipient.
- 14. **Project Management** - Explain key concepts in project management, and develop solutions to well-defined project management problems.
- 15. **Business and Public Administration** - Explain key concepts and processes used in business, public policy, and public administration.
- 16. **Cultural and Global Awareness** - Analyze and interpret cultural perspectives and social systems that define human characteristics.

* The civil engineering program uses the term "educational objective" to describe the expected accomplishments of our students in three to five years following graduation. The term "student learning outcome" is used to describe knowledge and skills at the time of graduation.

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Civil Engineering PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
	or	
	Elective(HSS)	
CLSK 100	College & Life Skills	1
CE 101	Engineering Surveying	2
Total		16

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
RH 131	Rhetoric and Composition	4
	or	
	Elective(HSS)	
CE 111	Geographic Info Systems	2
EM 102	Graphical Communications	2
	for CE	
Total		17

Spring Term		Credit
MA 113	Calculus III	5
EM 103	Introduction to Design	2
EM 120	Engineering Statics	4
	Elective (HSS)	4
Total		15

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
CHEM 111	General Chemistry I	4
EM 202	Dynamics	4
HSS	Elective	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
EM 203	Mechanics of Materials	4
CHEM 113	General Chemistry II	4
CE 250	Sustainable CE Design	2
	Elective (Science)***	4
Total		18

Spring Term		Credit
MA 223	Statistics for Engineers	4
EM 301	Fluid Mechanics	4
CE 320	C.E. Materials	4
CE 380	Transportation Engineering	4
Total		16

Junior Year

Fall Term		Credit
CE 321	Structural Mechanics I	4
CE 336	Soil Mechanics	4
CE 205	Thermodynamics	4
	or	
CHE 201	Conservation Principles and Balances	
CE 371	Hydraulic Engineering	4
Total		16

Winter Term		Credit
ECE 206	Elements of Electrical Eng. or	4
CHE 202	Basic Chemical Process Calculations	
CE 441	Construction Engineering	2
CE 432	Concrete Design I	3
CE 471	Water Resources Engineering	4
	Elective (Science)***	4
Total		17

Spring Term		Credit
CE 310	Civil Engineering Numerical Methods	2
CE 431	Steel Design I	3
CE 460	Environmental Engineering	4
RH 330	Technical and Professional Communication	4
CE 461	Environmental Engineering Lab	2
Total		15

Senior Year

Fall Term		Credit
CE 486	C.E. Design & Synthesis I	2
CE	**C.E. Elective	4
CE 450	C.E. Codes & Regulations	4
HSS	Elective	4
HSS	Elective	4
Total		18

Winter Term		Credit
CE 487	Technical System Design & Synthesis	2
CE 488	C.E. Design & Synthesis II	2
CE	**C.E. Elective	4
	*Elective (Technical)	4
CE 303	Engineering Economy	4
Total		16

Spring Term		Credit
CE 489	C.E. Design & Synthesis III	2
	*Elective(Technical)	4
HSS	Elective	4
HSS	Elective	4
CE 400	Career Preparation Seminar	0
Total		14
Total credits required:		194

***A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, biomathematics, or physics.**

****Student shall choose any 400 or 500 level CE elective course, designated with the"CE" prefix, as a CE Elective, in consultation with their advisor.**

*****At least 4 hours of science elective must be in a natural science outside Chemistry or Physics.**

Environmental Engineering Minor

The Environmental Engineering minor includes 6 required courses and 8 elective credit hours. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their interests.


The 6 required courses are as follows:

CE 460	Introduction to Environmental Engineering
CE 471	Water Resources Engineering
CHEM 264	Introduction to Environmental Science
CE 563/CHE 461	Unit Operations in Environmental Engineering
CE 564	Aquatic Environmental Chemistry
CHEM 251	Organic Chemistry I
CHEM 251L	Organic Chemistry I Laboratory

And 8 credit hours from the following courses:

CE 561/CHE 450	Air Pollution Control
CE 562	Treatability Studies
CE 565	Solid and Hazardous Waste Regulation and Treatment
CE 566	Environmental Management
CE 567	Applied Hydrologic Modeling
CE 568	Applied Contaminant Transport Modeling
CE 569	Environmental Systems Optimization
CE 573	Groundwater Analysis
CE 590	Special Problems
CE 598	Stream Restoration (Environmental River Mechanics)
CHE 465	Energy and the Environment
CHE 470	Safety, Health, and Loss Prevention
BIO 320	Ecology and Environmental Biology

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;
2. Function independently and in leadership positions within multidisciplinary teams;
3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;
4. Adapt and independently extend their learning to excel in fields about which they are passionate;
5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.

CPE student outcomes

At the time of graduation, students will have demonstrated:

1. an ability to apply knowledge of mathematics, science, and engineering
2. an ability to design and conduct experiments, as well as to analyze and interpret data
3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
4. an ability to function on multidisciplinary teams
5. an ability to identify, formulate, and solve engineering problems
6. an understanding of professional and ethical responsibility
7. an ability to communicate effectively
8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context
9. a recognition of the need for, and an ability to engage in life-long learning
10. a knowledge of contemporary issues
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The computer engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

COMPUTER ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term

Credit

Sophomore Year

Fall Term

Credit

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Intro to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
Total		17

Junior Year

Fall Term		Credit
MA 275	Discrete & Combinational Algebra I	4
CSSE 232	Computer Architecture I	4
ECE 380	Discrete-Time Signals	4
	or	
ECE 320	Linear Control Systems	
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
ECE 312	Communication Networks	4
HSS	Elective	4
CSSE 332	Operating Systems	4
	or	
CSSE 230	Data Structures and Algorithm Analysis	
	Math/Science Elective	4
Total		16

Spring Term		Credit
ECE 332	Computer Architecture II	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
Total		15

MA 211	Differential Equations	4
CHEM 111	General Chemistry I	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
Total		16

Spring Term		Credit
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
CSSE 220	Object Oriented Software Development	4
ECE 250	Electronic Device Modeling	4
Total		16

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
ECE 343	High Speed Digital Design	4
	Area Elective	4
HSS	Elective	4
Total		15

Winter Term		Credit
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
Total		16

Spring Term		Credit
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
Total		18
Total credits required:		194

AREA ELECTIVES

At least two of the three Area Electives must bear an ECE prefix at the 400 level or above
At most one of the Area Electives can bear an ECE or CSSE prefix at the 300 level or above
Exceptions to this requirement may be granted by the ECE Department Head

TECHNICAL ELECTIVE - Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering as a free elective or technical elective. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional mathematics or biomathematics classes to satisfy the departmental mathematics requirement, and any biology, chemistry, geology or physics courses to satisfy the departmental science requirement. Courses that are cross-referenced with any engineering courses will not satisfy either the mathematics or science requirements.

COMPUTER ENGINEERING CORE COURSES

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE312	Communication Networks	4
ECE332	Computer Architecture II	4
ECE343	High Speed Digital Design	4
ECE362	Principles of Design	3
ECE380	Discrete-Time Signals and Systems	4
or	or	
ECE320	Linear Control Systems	
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

SECOND MAJOR IN COMPUTER ENGINEERING

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE312	Communication Networks	4
ECE332	Computer Architecture II	4
ECE343	High Speed Digital Design	4
ECE380	Discrete-Time Signals and Systems	4

or	or	
ECE320	Linear Control Systems	
CSSE120	Introduction to Software Development	4
CSSE220	Object-Oriented Software Development	4
CSSE232	Computer Architecture I	4
CSSE332	Operating Systems	4
or	or	
CSSE230	Data Structures & Algor Analysis	
MA381	Intro to Probability w/ Apps to Stats	4
Total		66

MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Examples of Minors for Engineernig Physics and Optical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE180	Introduction to Signal Processing	4	ECE204	AC Circuits	4
ECE204	AC Circuits	4	ECE230	Introduction to Embedded Systems	4
ECE205	Circuits and Systems	4	ECE233	Introduction to Digital Systems	4
ECE300	Continuous-Time Signals Systems	4	ECE250	Electronic Device Modeling	4
ECE380	Discrete-Time Signals and Systems	4	ECE351	Analog Electronics	4
or	or				
ECE310	Communication Systems				

Examples of Minors for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Introduction to Signal Processing	4
ECE230	Introduction to Embedded Systems	4	ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4	ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4	ECE205	Circuits and Systems	4
ECE332	Computer Architecture II	4	ECE332	Computer Architecture II	4

Examples of Minors for Mechanical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Introduction to Signal Processing	4
ECE370	Power and Energy Systems	4	ECE204	AC Circuits	4
ECE371	Sustainable Energy Systems	4	ECE233	Introduction to Digital Systems	4
ECE470	Power Systems I	4	ECE250	Electronic Device Modeling	4
ECE471	Industrial Power Systems	4	ECE351	Analog Electronics	4

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)


Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Student Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering
13. Recognize the need for, and engage in, lifelong learning
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The computer science program is accredited by the Computing Accreditation Commission of ABET, www.abet.org

COMPUTER SCIENCE PLAN OF STUDY

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
Total		18
Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4
PH 112	Physics II	4
MA 112	Calculus II	5
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
Total		16
Winter Term		Credit
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
MA 375	Discrete & Combinatorial Algebra II	4

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Lang. Con.	4
ECE 332	Computer Architecture II	4
MA 381	Introduction to Probability with Applications to Statistics	4
RH 330	Technical and Professional Communication	4
Total		16

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 371	Software Requirements Engineering	4
CSSE/MA 473	Design and Analysis of Algorithms	4
CSSE	Elective	4
HSS	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
CSSE/MA 474	Theory of Computation	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE	Elective	4
	Technical Elective	4
Free	Elective	4
Free	Elective	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 487	Senior Research Project I or	4
CSSE 497	Senior Capstone Project I or	
CSSE 494	Senior Thesis I	
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 488	Senior Research Project II or	4
CSSE 498	Senior Capstone Project II or	
CSSE 495	Senior Thesis II	
CSSE	Elective	4
HSS	Elective	4
	Technical Elective	4
Total		14

<i>Spring Term</i>		<i>Credit</i>
CSSE 489	Senior Research Project III or	4
CSSE 499	Senior Capstone Project III or	
CSSE 496	Senior Thesis III	
Free	Elective	4
Free	Elective	4
Total		12
Total credits required:		192

CSSE electives cannot include any of CSSE 372, 373, 375, 376, and 477.
Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.
HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or

MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.

- 2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
- 3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
- 4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, biomathematics, or physics.
- 5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
- 6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 7. A total of 192 credits.

Area Minor in Computer Science

Advisor: J.P. Mellor

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

CSSE120 Introduction to Software Development
CSSE220 Object-Oriented Software Development
CSSE230 Data Structures and Algorithm Analysis
16 additional credits of computer science courses numbered above 200.
None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.



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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

- Learning Outcomes:**
- Upon graduating, Rose-Hulman Economics majors will be able to:
- 1. explain core economic terms, concepts and theories
 - 2. use economic theory to define, analyze and solve a wide range of problems.
 - 3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.
 - 4. communicate complex economics topics in both oral and written form.
 - 5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
or	or	
HSS	Elective	
SV 150	Intro to Microeconomics	4
or	or	
SV 152	Intro to Macroeconomics	
	Physical or Life Science	4
Total		18
Winter Term		Credit
MA 112	Calculus II	5
CSSE 120	Intro to Software Development	4
RH 131	Rhetoric and Composition	4
or	or	
SV 150	Intro to Microeconomics	
or	or	

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
	Economics Elective	4
	*HSS Elective	4
	Physical or Life Science	4
Total		16
Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Economics Elective	4
	*HSS Elective	4
	Physical or Life Science	4
Total		16
Spring Term		Credit
MA 381	Introd to Probability with Applications to Statistics	4
MA223	or	

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

SV 152	Intro to Macroeconomics		Engineering Statistics	
	Physical or Life Science	4	Economics Elective	4
	Total	17	*HSS Elective	4
Spring		Credit	Physical or Life Science	4
Term			Total	16
MA 113	Calculus III	5		
RH 131	Rhetoric and Composition	4		
or	or			
SV 150	Intro to Microeconomics			
or	or			
SV 152	Intro to Macroeconomics			
	Physical or Life Science	4		
	*HSS Elective	4		
	Total	17		

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

1. 24 credits of required Economics courses:
SV150 Introduction to Microeconomics
SV152 Introduction to Macroeconomics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX456 Seminar for HSS Senior Projects
XX457 Directed Study for HSS Senior Project
2. 20 additional credits in Economics electives.
3. 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA211, 212 Differential Equations, and Matrix Algebra and Systems of Differential Equations
MA223 Engineering Statistics I or
MA381 Introduction to Probability
4. 12 additional credits in mathematics or biomathematics other than MA351-356.
5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
7. 4 credits in Engineering Management
8. 4 credits in Computer Science: CSSE 120
9. CLSK 100 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
TOTAL	192



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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;

2. Function independently and in leadership positions within multidisciplinary teams;

3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;

4. Adapt and independently extend their learning to excel in fields about which they are passionate;

5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.

EE student outcomes

At the time of graduation, students will have demonstrated:

• an ability to apply knowledge of mathematics, science, and engineering

• an ability to design and conduct experiments, as well as to analyze and interpret data

• an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

• an ability to function on multidisciplinary teams

• an ability to identify, formulate, and solve engineering problems

• an understanding of professional and ethical responsibility

• an ability to communicate effectively

• the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

• a recognition of the need for, and an ability to engage in life-long learning

• a knowledge of contemporary issues

• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

ELECTRICAL ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term

Credit

PH 111

Physics I

4

Sophomore Year

Fall Term

Credit

MA 211

Differential Equations

4

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

https://www.rose-hulman.edu/course-catalog/course-catalog-2016-2017/programs-of-study/electrical-engineering.aspx[1/20/2017 12:13:44 PM]

MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Introduction to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
Total		17

Junior Year

Fall Term		Credit
ECE 380	Discrete-Time Signals and Systems	4
ECE 351	Analog Electronics	4
ECE 340	Electromagnetic Fields	4
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
ECE 320	Linear Control Systems	4
HSS	Elective	4
ECE 341	Electromagnetic Waves	4
	Math/Science Elective	4
Total		16

Spring Term		Credit
ECE 310	Communications Systems	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
Total		15

CHEM 111	General Chemistry	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
Total		16

Spring Term		Credit
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 370	Power & Energy Systems or	4
ECE 371	Sustainable Energy Systems	
ECE 250	Electronics Device Modeling	4
Total		16

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
	Math Elective	4
	Area Elective	4
HSS	Elective	4
Total		15

Winter Term		Credit
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
Total		16

Spring Term		Credit
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
Total		18
Total credits required:		194

AREA ELECTIVES

At least two of the three Area Electives must bear an ECE prefix at the 400 level or above
At most one of the Area Electives can bear an ECE or CSSE prefix at the 300 level or above
Exceptions to this requirement may be granted by the ECE Department Head

TECHNICAL ELECTIVE - Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering as a free electives or technical elective. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional mathematics or biomathematics classes to satisfy the departmental mathematics requirement, and any biology, chemistry, geology or physics courses to satisfy the departmental science requirement. Courses that are cross-referenced with any engineering courses will not satisfy either the mathematics or science requirements.

ELECTRICAL ENGINEERING CORE COURSES

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Microcontrollers	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE 371	Power & Energy Systems or Sustainable Energy Systems	3
ECE380	Discrete-Time Signals and Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

SECOND MAJOR IN ELECTRICAL ENGINEERING

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits Systems	4
ECE230	Introduction to Microcontrollers	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4

ECE351	Analog Electronics	4
ECE370	Power & Energy Systems	4
	or	
ECE371	Sustainable Energy Systems	
ECE380	Discrete-Time Signals and Systems	4
MA381	Introduction to Probability with Applications to Statistics	4
Total		66

MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor - ECE Department Head

Requirements for Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Example Minor for Engineering Physics and Optical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE180	Intro to Signal Processing	4	ECE204	AC Circuits	4
ECE204	AC Circuits	4	ECE230	Intro to Embedded Systems	4
ECE205	Circuits and Systems	4	ECE233	Intro to Digital Systems	4
ECE300	Continuous Time Signals and Systems	4	ECE250	Electronic Device Modeling	4
ECE380	Discrete-Time Signals and Systems	4	ECE351	Analog Electronics	4
or					
ECE310	or Communication Systems				

Examples Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits or	4	ECE203	DC Circuits	4
or	Electrical Systems		or	or	
ES203			ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Intro to Signal Processing	4
ECE230	Intro to Embedded Systems	4	ECE205	Circuits and Systems	4
ECE233	Intro to Digital Systems	4	ECE230	Intro to Embedded Systems	4
ECE250	Electronic Device Modeling	4	ECE233	Intro to Digital Systems	4
ECE332	Computer Architecture II	4	ECE332	Computer Architecture II	4

Examples Minor for Mechanical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Intro to Signal Processing	4
Required			ECE204	AC Circuits	4

ECE370	Power & Energy Systems	4	ECE233	Intro to Digital Systems	4
ECE371	Sustainable Energy Systems	4	ECE250	Electronic Device Modeling	4
ECE470	Power Systems I	4	ECE351	Analog Electronics	4
ECE471	Industrial Power Systems	4			

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

Enhanced Study in Communication Systems

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 312 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Continuous-Time Signals Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Minor in Communications (Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Circuits and Systems
- ECE300 Continuous-Time Signals Systems

- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

ENHANCED STUDY IN POWER SYSTEMS

Power Certificate

Take all of the following courses:

- ECE 473 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)


Required Courses

ECE 310 Communication Systems
OE 393 Fiber Optics and Applications
OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 312 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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- Outcome C: Design: Ability to design a product or process to satisfy client's needs subject to constraints.
- Outcome D: Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
- Outcome E: Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
- Outcome F: Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
- Outcome G: Communication: Ability to communicate effectively in oral, written and visual forms.
- Outcome H: Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Outcome I: Life Long Learning: A facility for independent learning and continued professional development.

ENGINEERING PHYSICS (Micro-Nano)

Freshman Year

Fall Term		Credit
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graphical Communications	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
EP 180	Engineering at Nanoscale*	2
EM 103	Introduction to Design**	2
Total		17*

Junior Year

Fall Term		Credit
PH 316	Electric and Magnetic Fields	4
ENG	200 Level Engineering Elective	4
PH 405	Semiconductor Materials and Applications	4
MA 223	Engineering Statistics I	4
Total		16

Winter Term		Credit
HSS	Elective	4
PH 317	Electromagnetism	4
RH 330	Technical and Professional Communication.	4

Sophomore Year

Fall Term		Credit
ECE 203	DC Circuits	4
PH 235	Many Particle Physics	4
MA 211	Differential Equations	4
SEM	Sci, Engr or Math Elective	4
Total		16

Winter Term		Credit
EP 280	Intro to Nano Engineering	4
PH 255	Foundations of Modern Physics	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 204	AC Circuits	4
Total		16

Spring Term		Credit
EP 380	Nano Technology Entrepreneurship and Ethics	4
OE 295	Optical Systems	4
SV 151	Principles of Economics	4
EM 121	Statics	4
Total		16

Senior Year

Fall Term		Credit
EP 416	Engineering Physics Project II	4
EP 407	Semiconductor Fabrication and Characterization	4
EP 411	Advanced MEMS	4
HSS	Elective	4
Total		16

Winter Term		Credit
EP 417	Engineering Physics Project III	4
ENG	300/400 Engineering Elective	4
HSS	Elective	4
PH 401	Intro Quantum Mechanics	4

EP 406	Semiconductor Devices and Fabrication	4	Total	16
Total		16	<i>Spring Term</i>	<i>Credit</i>
<i>Spring Term</i>		<i>Credit</i>	HSS	Elective
PH 327	Thermodynamics & Stat Mech	4	HSS	Elective
EP 410	Intro to MEMS	4	ENG	Engineering Elective
EP 415	Engineering Physics Project I	4	Free	Free Elective
HSS	Elective	4	Total	16
Total		16	Total credits required:	194

***If students miss EP 180 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level EP course of at least 2 credits.**

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

Subjects	#Classes	Hours
Physics(PH)	10	40
Math(MA)	6	27
Chemistry(CHEM)	2	8
ME	1	4
EM	3	8
CLSK	1	1
Electrical Engineering	2	8
Optical Engineering (OE)	2	6
HSS	9	36
Engineering Physics (EP)	6	24
Engineering Physics Project(EP)	3	12
Elective(SEM, Eng. and Free)	5	20
Total	50	194

SUMMARY OF GRADUATION REQUIREMENTS FOR ENGINEERING PHYSICS

- 1. All the courses listed above by the number.
- 2. The program must be approved by the EP advisor.
- 3. A list of the engineering electives is provided.
- 4. SEM (Science, Engineering, Math) electives are courses that need to be taken at the 200 level (CHEM115 is allowed) or above in biology, biomathematics, chemistry, computer science, engineering, mathematics or physics.
- 5. A free electives is any course in engineering, science, humanities, military science, or air science.

Classes by Subjects	Hours
Physics Coursework*	40
Chemistry and Mathematics Coursework**	35
Humanities and Social Science(Standard requirement)	36
EM, ME, CLSK Courses	13
Electrical Engineering Courses	8
Optical Engineering Courses	6
EP Courses	24
EP Projects	12
Engineering Electives	8
SEM and Free Electives	8
Total	193

Foundation Physics Classes

Course	Description	Hours
PH 235	Many Particle Physics	4

PH 255	Modern Physics	4
PH 316	Electric & Magnetic Fields	4
PH 317	Electromagnetism	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Introduction to Quantum Mechanics	4
Total		24

General Foundation Classes

Course	Description	Hours
PH 111	Physics I	4
PH 112	Physics II	4
PH 113	Physics III	4
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 223	Engineering Statistics	4
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
Total		47

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	2
OE 172	Lasers and Fiber Optics	2
EM 121	Statics I	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
EP 280	Introduction to Nano-engineering	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
OE 295	Photonic Devices and Systems	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
EP 411	Advance Topics in MEMS	4
EP 407	Semiconductor Fabrication % Characterization	4
	Engineering Elective	12
ME123	Computer Applications	4
Total		68

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	4
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Approved Engineering 200-Level Electives (4 credit hours required)

ECE 205	Circuits and Systems
ES 201	Conservation and Accounting Principles
ES 202	Fluid and Thermal Systems
EM 204	Statics II
OE 280	Geometric Optics
EP 290	Directed Study
EP 490	Directed Study

Approved Engineering Electives

- OE 360 Optical Materials
- OE 393 Fiber Optics
- OE 437 Introduction to Image Processing
- OE 450 Laser Systems and Applications
- OE 495 Optical Metrology
- EP 330 Materials Failure
- EP 450 Nanomedicine
- EP 470 Special Topics in Engineering Physics
- EP 490 Directed Study
- CHE 315 Materials Science and Engineering
- ME 328 Materials Engineering
- ME 417 Advanced materials Engineering
- ME 422 Finite Elements for Engineering Applications
- EM 403 Advanced Mechanics of Materials
- ECE 351 Analog Electronics
- ECE 250 Electronic Device Modeling



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computing industry and prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman international computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

International Computer Science Student Outcomes

By the time students graduate with an international computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools.
2. Anticipate complexities and problems involved in the development of large software systems.
3. Analyze requirements, design software that satisfies those requirements, and implement that software.
4. Analyze problems using ideas of problem complexity, models of computation, and decidability.
5. Design algorithms using a variety of paradigms.
6. Analyze algorithms in terms of correctness as well as time and space efficiency.
7. Communicate effectively, both verbally and in writing.
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry.
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering.
10. Collaborate effectively in small teams.
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering.
12. Explain the impact of globalization on computing and software engineering.
13. Recognize the need for, and engage in, lifelong learning.
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4
MA 112	Calculus II	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CSSE 232	Computer Architecture I	4
GE 111	German Language and Culture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete and Combinatorial Algebra I	4
Total		16

Winter Term		Credit
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
GE 112	German Language and Culture II	4
MA 375	Discrete and Combinatorial	4

Spring Term		Credit
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
CHEM 111	General Chemistry I	4
HSS	Elective	4
Total		17

Algebra II		
Total		16
Spring Term		Credit
CSSE 304	Programming Language Concepts	4
GE 113	German Language and Culture III	4
MA 381	Introduction to Probability with Statistical Applications	4
RH 330	Technical and Professional Communication	4
Total		16

Junior Year (at Hochschule Ulm, Germany)

First Semester		Credit
(CSSE225)	Programming 3	4
(CSSE371)	Software Project	4
(CSSE400)	Seminar	4
(CSSE Elective)	Special Subject A (Module 1)	4
(HSS Elective)	Technical German	4
(ECE233)	Digital Systems	4
Total		24

Second Semester		Credit
(CSSE212)	Hardware-oriented Programming	4
(CSSE332)	Operating Systems	4
(CSSE374)	Software Engineering	4
(CSSE432)	Computer Networks	4
(CSSE Elective)	Special Subject A (Module 2)	4
Free Elective		4
Total		24

Senior Year

Fall Term		Credit
CSSE 494	Senior Thesis I	4
MA371	Linear Algebra I	4
-or-	-or-	
MA373	Applied Linear Algebra for Engrs	
Science	Elective	4
Free	Elective	4
Total		16

Winter Term		Credit
CSSE 495	Senior Thesis II	4
CSSE/MA 474	Theory of Computation	4
HSS	Elective	4
Free	Elective	4
Total		16

Spring Term		Credit
CSSE 496	Senior Thesis III	4
CSSE/MA 473	Design and Analysis of Algorithms	4
Free	Elective	4
Total		12
Total Credits Required		192

Summary of graduation requirements for the international computer science major

HSS electives must be distributed as required by HSS. Science elective is any CHEM, PH, GEOL, or BIO course(s) totaling at least 4 credits.

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number, symbol, or name in the schedule of courses above: CSSE 120, CSSE 132, CSSE 220, CSSE 230, CSSE 304, CSSE or MA 473, CSSE or MA 474, and CSSE 494-6; MA 111, MA 112, MA 113, MA 212, MA 275, MA 375, MA 381; ECE 332; PH 111, PH 112; CHEM 111; RH 131, RH 330; GE 111, GE 112, GE 113; CLSK 100; BSYS, COMPA, DABA, ECHT, IPRO, RNET, SEM, VSYS, Technical German.
- 2. Four credits of science electives, which can be any CHEM, PH, BIO, or GEOL courses not already required for the international computer science major.
- 3. Eight additional credits of technical electives. Consisting of any courses in biology, chemistry, engineering

(except software engineering and engineering management), geology, mathematics, biomathematics, or physics.

- 4. Twelve credits of additional courses offered by the Department of Humanities and Social Sciences and/or appropriate humanities or social science courses offered at Hochschule Ulm. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences at Rose-Hulman.
- 5. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 6. A total of 192 credits.



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Mathematics

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of

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| Air Force ROTC (Military) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS) (Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Army ROTC (Military) |
| Pre-Professional Programs |

mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

DEGREE REQUIREMENTS

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics or biomathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core	12 hrs.
Three courses selected per the list below. Students completing the Continuous Applied	

Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics and biomathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450, BMTH496-498 not allowed).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry, mathematics modeling or application, or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- MA 493 and MA 494 must be taken in seperate terms.
- The requirement of MA 491-492 may be fulfilled through some project experience (such as an internship) and another 300-level or above mathematics course (4 hours), as approved by the project advisor. The course substitution procedure must be used.
- The project must involve work done by the student(s) to solve a problem presented by

an external sponsor or a problem with a substantial mathematical modeling, application and/or computational content. The written project submission must be approved by the advisor and/or sponsor, and must be presented publicly to the department.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team).
- The approved written thesis must be submitted to the department for archiving and must be publicly presented to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450, BMTH496-498 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.

Total hours required for graduation	195 hrs.
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* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
BIO 101 — Essential Biology (or higher-level BIO course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	
*** 200 level or above coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth. Coursework in mathematics and biomathematics is not allowed.	24 hrs.
**** CLSK 100 — College and Life Skills	1 hr.
MA 200 - Career Preparation (primary major only)	1 hr.

SUGGESTED SCHEDULE

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math

elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended science schedule of six science courses starts with PH 111. If CHEM 111 is required in the fall quarter because of a double major or minor, then the alternate science sequence may be completed by taking the second science course in each place where a choice is given. Two science courses are to be taken in the winter quarter of freshman year.

MATHEMATICS

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
	or	
CHEM 111	General Chemistry I	4
RH 131	Rhetoric and Composition	
	or	4
HSS	Elective	
CLSK 100	College and Life Skills	1
CSSE 120	Introduction to Software Development	4
Total		18

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
	or	
PH 111	Physics I	4
CHEM 111	General Chemistry I	
	or	4
BIO 101	Essential Biology (or higher level BIO course)	
HSS	Elective	4
	or	
RH 131	Rhetoric Composition	17
Total		

Spring Term		Credit
MA 113	Calculus III	5
PH 113	Physics III	4
	or	
PH 112	Physics II	2
MA 190	Contemporary Mathematics Problems	
HSS	Elective	4
Total		15

Junior Year

Fall Term		Credit
MA	Elective	4
	Technical Elective	4
	Technical Elective	4
HSS	Elective	4
	or	
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
MA 366	Functions of a Real Variable	4

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
MA 275	Disc. & Comb. Algebra I	4
BIO 101	Essential Biology (or higher level BIO course)	4
	or	
PH 113	Physics III	4
*CSSE 220	Object-Oriented Software Development	
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Science Elective	4
	Technical Elective	4
HSS	Elective	1
**MA 200	Career Preparation	
Total		17

Spring Term		Credit
MA 381	Introduction to Probability	4
MA 371	Linear Algebra I	4
	Technical Elective	4
HSS	Elective	4
Total		16

Senior Year

Fall Term		Credit
MA 491	Intro to Math Modeling (2 hours)	4
MA 492	Senior Project I (2 hrs.)	4
	or	
MA 496	Senior Thesis I (4 hrs.)	4
	Free Elective	
	Free Elective	4
HSS	HSS	
Total		16

Winter Term		Credit
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MA	Elective	4
	Technical Elective	
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
Total		16

Spring Term		Credit
MA	Elective	4
MA	Elective	4
	Technical Elective	4
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
Total		16

MA 493	Senior Project II (2 hrs.)	
	or	2
MA 497	Senior Thesis II (2 hrs.)	
MA	Elective	4
	Free Elective	4
	Free Elective	4
	Free Elective	4
Total		18

Spring Term		Credit
MA 494	Senior Project III (2 hrs.)	
	or	2
MA 498	Senior Thesis III (2 hrs.)	
MA	Elective	4
	Free Elective	4
	Free Elective	4
Total		14

Total credits required: 195

Notes:

- *MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework
- **MA 200 - Career Preparation - may be taken in the winter quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- Math Elective:** A course either required by the concentration or a true math elective.
- Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics; coursework in mathematics and biomathematics is not allowed.
- Free Elective:** Any course.

Computational Science Major (CPLS) (Second Major Only)

Computational methods are widely employed in science and engineering for simulation, experimentation, analysis, and design. In many areas the use of high-performance computing is essential. The Computational Science major provides Rose-Hulman students with the opportunity to add to their primary major a second major that increases their knowledge and skill in applied scientific and engineering computation.

Requirements for a second major in Computational Science (71 credit hours)

The second major in Computational Science is open to all students. It requires 71 credit hours, including a 55 credit hour core and a 16 credit hour specialization. The courses used to satisfy the requirements in the Advanced Core may not be counted toward any other major or minor. All Computational Science programs of study are subject to approval by the Chair of the Computational Science Steering Committee

I. Computational Science Core (51 credit hours)

Fundamentals (31 credit hours)

- MA 111, 112, 113 Calculus I, II, III
- MA 211 Differential Equations
- MA 212 Matrix Algebra and Systems of Differential Equations
- CSSE 120 Introduction to Software Development, or any of BE 100, CE 111 (plus 2 cr.), CHE 110

(plus 2 cr.), ME 123

- MA 332 Introduction to Computational Science

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any course from the list of Approved Computational Science Electives (or another upper-level course if approved by the Chair of the Computational Science Steering Committee):

- BE 340 Biomedical Signal Processing
- BE 510 Biomedical Signal and Image Processing
- BMTH 312 Bioinformatics
- BMTH 413 Computational Biology
- CHE 310 Numerical Methods for Chemical Engineers
- CE 310 Computer Applications in Civil Engineering
- CSSE 304 Programming Language Concepts
- ECE 480/OE 437 Introduction to Image Processing
- ECE 483 DSP System Design
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 384 Data Mining
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis
- MA 435 Finite Difference Methods
- MA 439 Mathematical Methods of Image Processing
- MA 444 Deterministic Models in Operations Research
- MA 446 Combinatorial Optimization
- ME 422 Finite Element Methods for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 430 Mechatronic Systems
- ME 522 Advanced Finite Elements Analysis
- ME 536 Computational Intelligence in Control Engineering
- PH 540 Computer Physics

II. Area of Concentration (20 credit hours): Each student must complete 20 credit hours of advanced work reflecting an Area of Concentration within Computational Science. Courses used to satisfy the core requirements may not be used to satisfy the area of concentration requirements. The 20 credit hours shall consist of at least 16 credit hours within a single Area of Concentration, as specified below, and an additional 4 credit hours from any of the Areas of Concentration, or from the list of Approved Computational Science Electives. Exceptions may be made on occasion (e.g. when an appropriate special topics course has been taken).

Computational Methods

- MA 371 or MA 373 Linear Algebra I, Applied Linear Algebra for Engineers
- MA 433 Numerical Analysis
- Eight credit hours chosen from BMTH 413, CSSE 304, CSSE/MA 473, MA 384, MA 386, MA 434, MA 435, MA439, MA 444, MA 446, MA 485, ME 422

Computational Mechanics

- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- ME 401 Foundations of Fluid Mechanics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Element Analysis

Computational Signals and Image Processing

- ECE 380 Discrete-Time Signals and Systems
- ECE 480/OE 437 Introduction to Image Processing
- ECE 483 DSP System Design

- MA 439 Mathematical Methods of Image Processing

Computational Physics and Chemistry

- CHEM 361 Physical Chemistry I
- CHEM 362 Physical Chemistry II
- CHEM 363 Quantum Chemistry & Molecular Spectroscopy
- OE 570 Nanomedicine
- PH 540 Computer Physics

Computational Biomedics

- BE 482/MA 482 Bioengineering Statistics
- BE 535/OE 535 Biomedical Optics
- BE 541/ECE 584 Medical Imaging
- BMTH 310 Mathematical Biology
- BMTH 413 Computational Biology

AREA MINOR IN MATHEMATICS

Any student not pursuing a major or second major in either mathematics or in biomathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), all BMTH courses numbered 300 or higher (except BMTH 496-498), or other MA courses approved by the minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211, MA212 and one of MA223, MA381, or MA382 can be counted towards any combination of the multiple minors offered by the mathematics department.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

AREA MINOR IN COMPUTATIONAL SCIENCE

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling

- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the

major.

- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

AREA MINOR IN STATISTICS


Any student not pursuing a major or second major in mathematics nor in biomathematics may obtain an area minor in statistics by taking ten or more mathematics courses (43 credit hours) including the following:

- **19 credit hours - Foundational Mathematics Courses:**
MA 111 Calculus I
MA 112 Calculus II
MA 113 Calculus III
MA 212 Differential Equations and Matrix Algebra
- **8 credit hours - Required Statistics and Probability Courses**
MA 381 Introduction to Probability with Applications to Statistics
One of the following:
MA223 Engineering Statistics I
MA382 Introduction to Statistics with Probability
If MA 381 is taken before MA223/MA382, it will be strongly recommended the student take MA382 instead of MA223.
- **16 credit hours - Secondary Statistics Courses**
Four courses selected from the following list, at least two of which must be starred (*). Statistics courses not on this list may count towards the minor if approved by the statistics minor advisor.
MA 383* Engineering Statistics II
MA 385 Quality Methods
MA 386* Statistical Programming
MA 387 Statistical Methods in Six Sigma
MA 445 Stochastic Models in Operations Research
MA 481 Mathematical Statistics
MA 482* Bioengineering Statistics
MA 485* Applied Regression and Time Series Analysis
MA 487* Design of Experiments
MA 480 Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the foundational mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211, MA212 and one of MA223, MA381, or MA382 can be counted towards any combination of the multiple minors offered by the mathematics department.
- No student can take both MA223 and MA382 for credit.



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| Electrical Engineering |
| Engineering Physics |
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| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- | |
|---|
| Air Force ROTC (Military) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS) (Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Army ROTC (Military) |
| Pre-Professional Programs |

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

- a. *an ability to apply knowledge of mathematics, science, and engineering*
- b. *an ability to design and conduct experiments, as well as to analyze and interpret data*
- c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
- d. *an ability to function on multi-disciplinary teams*
- e. *an ability to identify, formulate, and solve engineering problems*
- f. *an understanding of professional and ethical responsibility*
- g. *an ability to communicate effectively*
- h. *the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
- i. *a recognition of the need for, and an ability to engage in life-long learning*
- j. *a knowledge of contemporary issues*
- k. *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*

Minor* in Thermal-Fluids

To complete the requirements of the thermal-fluids minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid Systems
or
- CE 205 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

ME 301 Applications of Thermodynamics
CHE 303 Chemical Engineering Thermodynamics
ME 302 Heat Transfer
CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems

- ME 407 Power Plants**
- ME 408 Renewable Energy
- ME 409 Air Conditioning***
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems**
- ME 426 Turbomachinery
- ME 462 Thermal Design

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 405 Theoretical Aerodynamics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 450 Combustion
- ME 501 Advanced Thermodynamics**
- ME 510 Gas Dynamics

Successful completion of a minor is indicated on the student's transcript. A student interested in pursuing a minor in thermal-fluids should consult with the head of the Department of Mechanical Engineering.

* ME Majors do **not** qualify for the Thermal Fluids Minors, but may pursue ME Concentrations.
** Requires one of the thermodynamics prerequisites from section 2 above.
*** Requires one of the heat transfer prerequisites from section 2 above.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may add special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Area of Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Five elective courses are required which permit students to provide either depth or breadth according to their interests.

Elective Courses

CHEM 470 Combustion Chemistry

ECE 320 Linear Control Systems
or
ME 406 Control Systems

ECE 420 Nonlinear Control Systems
or
ME 506 Advanced Control Systems

ECE 370 Machines & Power
ECE 410 Communication Networks
ECE 452 Power Electronics
ME 401 Foundations of Fluid Mechanics
ME 405 Theoretical Aerodynamics
ME 408 Renewable Energy
ME 410 Internal Combustion Engines
ME 411 Propulsion Systems
ME 422 Finite Elements for Engineering Applications
ME 426 Turbomachinery
ME 427 Introduction to Computational Fluid Dynamics
ME 447 Visualizing Data
ME 450 Combustion
ME 497 Three Dimensional Dynamics

ME 522 Advanced Finite Element Analysis

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills to aerospace systems.

The courses required to complete the concentration are as follows:

ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

MA 336 Boundary Value Problems

EM 505 Theory of Elasticity

ME 401 Foundations of Fluid Mechanics

ME 405 Theoretical Aerodynamics

ME 410 Internal Combustion Engines

ME 411 Propulsion Systems

ME 422 Finite Elements for Engineering Applications

ME 426 Turbomachinery

ME 427 Introduction to Computational Fluid Dynamics

ME 461 Aerospace Design

ME 510 Gas Dynamics

ME 522 Advanced Finite Element Analysis

PH 322 Celestial Mechanics

Industrial Leadership Area of Concentration

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

MA 385 Quality Methods

MA 487 Design of Experiments

MA 387 Statistical Methods in Six Sigma

Engineering Management List

EMGT 330 Introduction to Engineering Management

EMGT 520 Accounting for Technical Managers

EMGT 522 Organizational Management

EMGT 523 Marketing Issues in a Technical Environment 4

EMGT 524 Production/Operations Management

EMGT 525 Human Resources Management

EMGT 526 Innovation Management and Forecasting

EMGT 527 Project Management

EMGT 531 Economics for Technical Managers

EMGT 532 Technical Entrepreneurship

EMGT 533 Intercultural Communication

EMGT 535 Strategies for Organizational Change

EMGT 567 Economic Analysis of Engineering Projects

EMGT 586 Supply Chain Management

EMGT 587 Systems Engineering

EMGT 588 Quality Management I

EMGT 589 Manufacturing Systems

EMGT 598 Operational Research for Technical Managers

Humanities, Social Sciences List

GS 350 International Trade

GS 351 International Finance

IA 230 Fundamentals of Public Speaking

IA 352 Game Theory

SV 150 Introduction to Microeconomics

SV 152 Introduction to Macroeconomics

SV 351 Managerial Economics

SV 357 Labor Economics

SV 303 Business and Engineering Ethics

SV 304 Bioethics

SV 352 Money & Banking

SV 353 Industrial Organization

SV 354 Environmental Economics

SV 356 Corporate Finance

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

List 1:

EMGT 330 Introduction to Engineering Management

EMGT 524 Production/Operations Management

EMGT 527 Project Management

EMGT 588 Quality Management

EMGT 589 Manufacturing Systems

EMGT 598 Lean Six Sigma

MA 385 Quality Methods

MA 387 Statistical Methods in Six Sigma

ME 317 Design for Manufacturing

ME 397 Advanced CAD

ME 397 Design for Additive Manufacturing

ME 435 Robotics

ME 497 Lean Manufacturing

ME 520 Computer Aided Design and Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

List 2:

SV 150 Introduction to Microeconomics

SV 152 Introduction to Macroeconomics

SV 171 Principles of Psychology

SV 351 Managerial Economics

SV 356 Corporate Finance

IA 453 The Entrepreneur

Students must complete five courses from List 1 and three of the recommended HSS courses from List 2 to obtain the concentration in manufacturing and production.

Dynamic Systems & Control Area of Concentration

Mechanical engineering graduates may work in industries, such as the automotive and aerospace industries, in

which the understanding and control of a system's dynamic response is critical. The dynamic systems & control concentration provides students with experiences in modeling, analysis, and simulation of the dynamic behavior of systems with and without feedback control, as well as opportunities to explore data collection for vibratory systems and control algorithm implementation in a laboratory setting.

To complete the requirements of the area of concentration in Dynamics Systems & Control, students must complete five courses from this list:

- ME 403 Kinematics of Machinery
- ME 406 Control Systems
- ME 497 Three-Dimensional Dynamics
- ME 506 Advanced Control Systems
- ME 536 Computational Intelligence in Control Engineering
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- PH 322 Celestial Mechanics

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery
- ME 462 Thermal Design

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 405 Theoretical Aerodynamics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 450 Combustion
- ME 501 Advanced Thermodynamics
- ME 510 Gas Dynamics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the **Thermal Fluid Systems**list and at least two courses are taken from the **Thermal Fluid Sciences**list.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

MECHANICAL ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
RH 131	Rhetoric and Composition split or fall or winter with Elective	4
HSS		
Total		16

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
ES 201	Conservation & Accounting Principles	4
ES 203	Electrical Systems	4
HSS	Elective	4
Total		16
Winter Term		Credit
MA 212	Matrix Algebra and Systems	4

<i>Winter Term</i>		<i>Credit</i>
MA 112	Calculus II	5
PH 112	Physics II	4
EM 121	Statics and Mechanics of Materials I	4
RH 131 or HSS	Rhetoric and Composition split fall or winter with Elective	4
Total		17

<i>Spring Term</i>		<i>Credit</i>
MA 113	Calculus III	5
PH 113	Physics III	4
EM 103	Introduction to Design	2
ME 123	Computer Applications I	4
Total		15

Junior Year

<i>Fall Term</i>		<i>Credit</i>
ME 301	Applications of Thermodynamics	4
EM 204	Statics & Mechanics of Materials	4
ME406 or EM 406	Control Systems or Vibration Analysis	4
Free*	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
ME 317	Design for Manufacturing	4
ME 321 or	Measurement Systems (4) split winter or spring with	
ME323 and MA/Science	Numerical Methods in Engineering and Math or Science Elective	2 4
ME 328	Materials Engineering	4
RH 330 or HSS	Technical Communications split winter or spring with HSS Elective	4
Total		18 or (16)

<i>Spring Term</i>		<i>Credit</i>
ME 302	Heat Transfer	4
ME 323 and MA/Science	Numerical Methods in Engineering (2) and Math or Science Elective (4)	
or ME 321	split winter or spring with Measurement Systems	4
ME 480	Machine Component Design	4
HSS or RH 330	Elective split winter or spring with Technical	4

of Differential Equations		
ES 202	Fluid & Thermal Systems	3
ES 204	Mechanical Systems	3
CHEM 111	General Chemistry I	4
HSS	Elective	4
Total		18

<i>Spring Term</i>		<i>Credit</i>
MA 223	Statistics for Engineers	4
ES 205	Analysis & Design of Engineering Systems	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
ME 430 or ME 421	Mechatronic Systems (4) split fall or winter with M.E. Lab (2)	4
ME 470	Capstone Design I	4
Tech*	Elective	4
Tech*	Elective	4
Total		16 or (14)

<i>Winter Term</i>		<i>Credit</i>
ME 471	Capstone Design II	4
ME 421 or ME 430	M.E. Lab (2) split fall or winter with Mechatronic Systems (4)	2
HSS	Elective	4
Free*	Elective	4
Total		14 or (16)

<i>Spring Term</i>		<i>Credit</i>
ME 472	Capstone Design III	4
Tech*	Elective	4
Tech*	Elective	4
HSS	Elective	4
Total		16
Total credits required:		194

Communications	
Total	16 or (18)

*28 credit hours. in electives composed of 16 cr. hrs. in technical electives and 8 cr. hrs. in free electives.

*A **technical elective** is any course (at the 200 level or above) in biomathematics, chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A **math elective** has an MA or BMTH prefix.

A **science elective** is any course in biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.



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Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>

OE Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will make a meaningful impact on society.
- Our graduates will behave ethically and act as responsible members of the engineering and science community.
- Our graduates will continue to develop professionally

OE Student Learning Outcomes

Outcome A: An ability to apply knowledge of mathematics, science, and engineering

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

Outcome B:	An ability to design and conduct experiments, as well as to analyze and interpret data
Outcome C:	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
Outcome D:	An ability to function on multidisciplinary teams
Outcome E:	An ability to identify, formulate, and solve engineering problems
Outcome F:	An understanding of professional and ethical responsibility
Outcome G:	An ability to communicate effectively
Outcome H:	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
Outcome I:	A recognition of the need for, and an ability to engage in life-long learning
Outcome J:	A knowledge of contemporary issues
Outcome K:	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Optical Engineering graduation data <http://www.rose-hulman.edu/media/1262267/oe.pdf>

The optical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

OPTICAL ENGINEERING

Freshman Year

<i>Fall Term</i>		<i>Credit</i>
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graph Comm	2
Total		16

<i>Winter Term</i>		<i>Credit</i>
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4
Total		17

<i>Spring Term</i>		<i>Credit</i>
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
OE 172	Lasers and Fiber Optics *	2
EM 103	Intro Eng. Design	2
Total		17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
OE 392	Linear Optical Systems	4

Sophomore Year

<i>Fall Term</i>		<i>Credit</i>
PH 235	Many-Part Physics	4
PH 292	Physical Optics	4
MA 211	Differential Equations	4
ECE 203	DC Circuits	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
ECE 204	AC Circuits	4
PH 255	Fnd. of Mod. Phys.	4
MA 212	Matrix Algebra & Sys of Diff Equat	4
OE 280	Geometrical Optics	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
OE 295	Photonic Devices & Systems	4
SV 151	Principles of Economics	4
MA 223	Engineering Statistics	4
	Free Elective	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
OE 416	Optical Eng Design II	4

OE 395	Opto-Mech & Optical Eng Lab	4	OE 480	Optical System Design	4
PH 316	Elec & Mag Fields	4	PH 405	Semiconductor Materials & Appl	4
HSS	Elective	4	HSS	Elective	4
Total		16	Total		16

Winter Term		Credit	Winter Term		Credit
OE 393 or OE 360	Fiber Optics & Applications or Optical Materials	4	OE 417	Optical Engineering Design III	4
RH 330	Tech & Prof Communications	4	OE 495	Optical Metrology	4
HSS	Elective	4	OE 393 or OE 360	Fiber Optics and Applications or Optical Materials	4
	Free Elective	4	PH/OE/EP	Elective ***	4
Total		16	Total		16

Spring Term		Credit	Spring Term		Credit
OE 415	Opt Eng Des I	4	HSS	Elective	4
OE 450	Laser Systems & Applications	4	HSS	Elective	4
HSS	Elective	4		Engineering Elective**	4
	Engineering Elective**	4		Free Elective	4
Total		16	Total		16

Total credits required: 194

*If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

**An engineering elective is any 200, 300, or 400-level course listed as OE, EP, ECE, ME, CE, BE, EM or ES.

***A PH/OE/EP elective is any 200, 300, or 400-level course listed as OE, EP or PH.

SUMMARY OF GRADUATION REQUIREMENTS FOR OPTICAL ENGINEERING

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in biology, biomathematics, chemistry, computer science, engineering, mathematics, or physics

Classes by subjects	Hours
Optics Coursework	46
Physics Coursework	20
Freshmen Physics, Chemistry and Mathematics Coursework	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous	25
Total	194

Physics Classes		
Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4
PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4

Total	20
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Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM111	Engineering Chemistry I	4
CHEM113	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
Total		17

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Diteon, Duree, Granieri, Joenathan, Leisher, Siahmakoun, and Wagner.

Required Courses (12 hours)

Course	Hours	Course Description
OE 280	4	Geometrical Optics
PH 292	4	Physical Optics
OE 295	4	Photonic Devices and Systems

Plus at least two courses (8 hours) from the list below:

Course	Hours	Course Description
OE 360	4	Optical Materials
OE 392	4	Linear Optical Systems
OE 393	4	Fiber Optics and Applications
OE 395	4	Optomechanics & Optial Engineering Lab
OE 434	4	Non-Imaging Optics
OE 435	4	Biomedical Optics
OE 437	4	Introduction to Image Processing
OE 450	4	Laser Systems and Applications
OE 470	4	Special Topics in Optical Engineering
OE 480	4	Optical System Design
OE 493	4	Fundamentals of Optical Fiber Communications
OE 495	4	Optical Metrology

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)

Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203	4	DC Circuits
ECE 204	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an

interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

PHYSICS

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
RH 131 or HSS	Rhetoric and Comp or HSS Elective	4
EM 104	Graphical Communications	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 111	General Chemistry I	4
	Computing Elective*	2-4
Total		15 or 17

Spring Term		Credit
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Sophomore Year

Fall Term		Credit
	Free Elective†	4
PH 235	Many Particle Physics	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
PH 292	Physical Optics	4
Total		16

Winter Term		Credit
PH 255	Fund. of Modern Physics	4
HSS	Elective	4
	Technical Elective	4
MA 211	Differential Equations	4
Total		16

Spring Term		Credit
PH 314	Theoretical Mechanics I	4

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

PH 113	Physics III	4
MA 113	Calculus III	5
CHEM 113	General Chemistry II	4
HSS or RH131	HSS Elective or Rhetoric and Composition	4
Total		17

Junior Year

Fall Term		Credit
HSS	Elective	4
PH 316	Electric and Magnetic Fields	4
	Technical Elective†	4
PH 405	Semiconductor Materials and Applications	4
Total		16

Winter Term		Credit
PH 317	Electromagnetism	4
PH 401	Intro Quantum Mechanics	4
HSS	Elective	4
	Physics Elective†	4
Total		16

Spring Term		Credit
PH 325	Advanced Physics Lab I	4
HSS	Elective	4
OE 450	Laser Sys & App or Physics Elective†	4
PH 327	Thermodynamics & Statistical Mechanics	4
Total		16

HSS	Elective	4
MA 371 -or- MA 373	Linear Algebra I -or- Applied Linear Algebra for Engr	4
	Math Elective†	4
Total		16

Senior Year

Fall Term		Credit
Math	Elective†	4
	Technical Elective†	4
HSS	Elective	4
	Free Elective	4
Total		16

Winter Term		Credit
PH 425	Advanced Physics Lab II	4
HSS	Elective	4
	Technical Elective†	4
	Free Elective†	4
Total		16

Spring Term		Credit
	Technical Elective†	4
OE 450	Laser Sys & App or Physics Elective	4
	Free Elective	4
	Physics Elective†	4
Total		16

Total credits required: 192

* Computing elective: 2 or 4 credit course on computing from the following course: BIO 100, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

SUMMARY OF GRADUATION REQUIREMENTS FOR PHYSICS MAJORS

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
6. Sixteen credits of free electives (cannot include ECE340).
7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
8. A technical elective is any RHIT course in biology, biomathematics, chemistry, computer science, engineering, mathematics, or physics.

9. A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
PH 215	Introduction to Chaos	2
PH 231	Intro to Astronomy and Astrophysics	4
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 322	Celestial Mechanics and Solar	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
PH 407	Solid State Physics	4
PH 410	General Relativity	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	Arranged
PH 470	Directed Research	Arranged
PH 480	Seminar	Arranged
PH 490	Directed Research	Arranged
PH 497+	Senior Thesis	Arranged
PH 498+	Senior Thesis	Arranged
PH 499+	Senior Thesis	Arranged
PH 512	Methods of Mathematical Physics	4
PH 514	Quantum Mechanics	4
PH 530	Advanced Acoustics	4
PH 537	Advanced Image Processing	4
PH 538	Introduction to Neural Networks	4

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year for a total number of 8 credit hours over the three quarter sequence. Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

**Math and Chemistry Courses:

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Linear Algebra	

MA 371	General Chemistry I	4
CHEM 111	General Chemistry II	4
CHEM 113		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

The course requirements and advisors for Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an minor is indicated on the student's grade transcript. A student interested in pursuing an minor should consult with the appropriate advisor.

Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus 12 credit hours from the following courses:

Course	Course Title	Hours
PH 270/470	Special Topics in Physics †	ARR
PH 290/490	Directed Research †	ARR
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4
PH 410	General Relativity	4
PH 460	Directed Study †	ARR

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be

counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

A Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 410	General Relativity	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4

EP 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

A Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowitz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
OE 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

A Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4


ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

A Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>



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Prospective Students
Current Students
Incoming Freshman

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Alumni and Friends
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Industry Partners
Trustees
Parents

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

The software engineering program prepares its graduates for many types of careers in the computing industry as well as for graduate study in software engineering and in closely related disciplines. Within a few years after completing the software engineering degree program, our graduates will:

- Advance beyond their entry-level position to more responsible roles, or progress towards completion of advanced degree(s).
- Continue to keep pace with advancements in their disciplines, and develop professionally in response to changes in roles and responsibilities.
- Demonstrate that they can collaborate professionally within or outside of their disciplines at local, regional, national, or international levels.
- Contribute to the body of computing products, services, or knowledge.

Software Engineering Student Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The software engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

SOFTWARE ENGINEERING

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric & Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term	Credit
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Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
Total		16

CSSE 220	Object-Oriented Software Development	4
MA 112	Calculus II	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems Design	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 371	Software Requirements Engineering	4
CSSE 372	Software Project Management	4
MA 381	Introduction to Probability with Statistical Applications	4
	Domain track course	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
HSS	Elective	4
	Domain track course	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 373	Formal Methods in Specification and Design	4
CSSE 375	Software Construction and Evolution	4
HSS	Elective	4
	Domain track course or free elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
MA 375	Discrete & Combinatorial Algebra II	4
	Domain track course	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Lang. Con	4
CSSE 376	Software Quality Assurance	4
MA	Elective	4
RH 330	Technical and Professional Communication	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 477	Software Architecture	4
CSSE 497	Senior Capstone Project I	4
HSS	Elective	4
	Domain track course or free elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 498	Senior Capstone Project II	4
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 499	Senior Capstone Project III	4
HSS	Elective	4
Free	Elective	4
Total		12

Total credits required: 192

Summary of graduation requirements for the software engineering major

To complete the major in software engineering a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE477, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA212, MA275, MA375, MA381; PH111, PH112, CHEM111; RH 131, RH330; CLSK100.
2. Four additional credits of CSSE courses except CSSE325, CSSE473, CSSE474, and CSSE479. In addition, use of CSSE49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.
3. A Domain Track set of courses. All of the courses for each of the [Domain Tracks](#) is listed on the CSSE website. That site also explains the procedures and deadlines by which a student must declare their Domain Track.

- 4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
- 5. Four credits of science electives, which can be any CHEM, GEOL, PH, or BIO courses not already required for the software engineering major.
- 6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
- 7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

CSSE 120, Introduction to Software Development
CSSE 220, Object-Oriented Software Development
CSSE 230, Data Structures and Algorithm Analysis
CSSE 371, Software Requirements Engineering
CSSE 374, Software Design

Two additional courses in software engineering chosen from CSSE 372, 373, 375, 376, and 477.



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Information For

Prospective Students
Current Students
Incoming Freshman

Faculty and Staff
Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Air Force ROTC (Military)

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation-contact Air Force ROTC for more details.

SCHOLARSHIPS

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

- Profession of Arms** Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.
- Communications Skills** Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

General Military Courses

Freshman Year		Credit
AS 101	Found. of the US Air Force I	1
AS 101L	Leadership Laboratory	0
AS 102	Found. of the US Air Force II	1
AS 102L	Leadership Laboratory	0
AS 103	Found. of the US Air Force III	1
AS 103L	Leadership Laboratory	0

Sophomore Year		Credit
AS 201	Evol. of Air & Space Power I	2
AS 201L	Leadership Laboratory	0
AS 202	Evol. of Air & Space Power II	2
AS 202L	Leadership Laboratory	0
AS 203	Evol. of Air & Space Power III	2
AS 203L	Leadership Laboratory	0

Professional Officer Courses


Junior Year		Credit
AS 301	Air Force Lead. Studies I	4
AS 301L	Leadership Laboratory	0
AS 302	Air Force Lead. StudiesII	4
AS 302L	Leadership Laboratory	0
AS 303	Air Force Lead. Studies III	4
AS 303L	Leadership Laboratory	0

Senior Year		Credit
AS 401	Nat.Sec.Aff./Prep. for Active Duty I	4
AS 401L	Leadership Laboratory	0
AS 402	Nat.Sec.Aff./Prep. for Active Duty II	4
AS 402L	Leadership Laboratory	0
AS 403	Nat.Sec.Aff./Prep. for Active Duty III	4
AS 403L	Leadership Laboratory	0

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.



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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Humanities and Social Sciences

AREAS OF STUDY

Global Studies

Ideas and Art

Society and Values

Modern Languages

MAJORS

Economics

International Studies (second major only)

GERMAN TECHNICAL TRANSLATION CERTIFICATE

MINORS

Anthropology

Art

East Asian Studies

Economics

European Studies

Geography

German

History

Japanese

Language and Literature

Latin American Studies

Modern Languages

Music

Political Science

Philosophy and Religion

Psychology

Spanish

Theatre and Drama

Professors Bremmer, Carlson, Carvill, Casey, Chapman, Christ, Christensen, Dyer, Findley, Garcia, Gardner, Garner, Grose, Hartner, Hartnett, Heeter, Hirotani, House, Jern, Kim, Kukral, Letsinger, Livingston, Martland, Michel, Minster, Smith Roads, Summers, Taylor, Watt, and Williams.

MISSION STATEMENT

To enable our students to become creative, sophisticated thinkers, active citizens, and effective leaders in the global community, the department contributes to a broad liberal education, introducing students to a wide array of disciplines and traditions in the humanities and social sciences. In doing so, it provides learning experiences that, in addition to their intrinsic value, enrich a scientific and technical education.

Educational Objectives

Within the context of a liberal education, the department fosters in its students the desire and the ability to:

think critically

, forming cogent, informed opinions, defining and solving problems with an awareness that societal processes are complex and interactive;

communicate effectively

to diverse audiences, including those from other cultures and communities;

succeed in a global context

by understanding and adapting to diverse cultures, alternative points of view, and the challenges of globalization;

exhibit ethical and responsible leadership

as individuals, citizens, and professionals, committed to lifelong learning and achievement.

Disciplines

The HUMANITIES study what it means to be human within a contemporary or historical context. These

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

https://www.rose-hulman.edu/course-catalog/course-catalog-2016-2017/course-descriptions/humanities-and-social-sciences.aspx#intl-studies[1/20/2017 12:16:33 PM]

disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art and Art History	Anthropology
English and Literature	Archaeology
Foreign Languages(German, Japanese, and Spanish)	Economics
History	Geography
Music	Political Science
Philosophy and Religion	Psychology
Theater	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- **Global Studies (GS prefix):** Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- **Ideas and Arts (IA prefix):** Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.
- **Society and Values (SV prefix):** Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communication are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communication is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general **lower level courses (100 and 200 level)** tend to be broad surveys of particular subject areas within disciplines. **Upper level courses (300 and 400 level)** are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General

- All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

- All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted free elective transfer credit, but are not exempted from RH 131.
- **EXEMPTION:** An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. Any HSS course may be substituted for RH 131 for exempted students.
 1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic

Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.

2. Has received grades of B or higher in all high school English courses.

- **INTERNATIONAL STUDENTS:** International students for whom English is not their native language will be required to take an assessment test to gauge their written, oral, and listening proficiency in English. The purpose of this testing is to ensure that all students have the proper communication skills to advance successfully through the challenging Rose-Hulman curriculum. Based on this assessment, some students will be required to take CLSK121 College English. Those students must successfully complete CLSK121 prior to taking RH131 Rhetoric and Composition.

3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.
 1. A minimum of two terms of the same language (or the equivalent thereof) must be completed in order to apply foreign language credits toward Humanities and Social Sciences requirements. If only SP111, JP111 or GE111 is completed, that course will not be allowed to satisfy an HSS requirement. For transfer credit, a single foreign language course at 4 credit hours may be used to satisfy an HSS requirement if it is higher than the entry level course (xx111) in that language. Example: Transfer credit awarded for SP113 could be used to satisfy one HSS course requirement.
 2. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.
 3. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three thematic categories as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each thematic category in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
 4. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
 5. Students may not earn foreign language credit in their native languages.
 6. Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. Minors

- Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

HELP WITH REQUIREMENTS

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies,

Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, Spanish or Theatre and Drama by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

<i>Minor</i>	<i>Advisor</i>
Anthropology	Paul Christensen
Art	Steve Letsinger
East Asian Studies	Tim Grose
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter
Geography	Michael Kukral
History	Samuel Martland
Japanese	Maki Hirotani
Language and Literature	Caroline Carvill
Music	David Chapman
Latin American Studies	Gustavo Garcia
Philosophy and Religion	Dan Hartner
Political Science	Terrence Casey
Psychology	Alan Jern
Spanish	John Gardner
Theatre and Drama	Terence Hartnett

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Intro to East Asia 4R-OL-4C

Examines the changing political, economic, and cultural orders in East Asia.
(NOTE: formerly Intro to East Asian History)

GS 130 Introduction to Sustainability 4R OL 4C Prereq: Admission to HERE Program or Consent of Instructor

Surveys the fundamentals of sustainability in scientific, technical, and social contexts. Introduces students to the history of environmentalism and sustainability, along with the basics of ecology, climate assessment, natural cycles, life cycle analysis, environmental economics, and other concepts.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 185 Introduction to Anthropology 4R-OL-4C

Examines human adaptation and diversity as well as the development and variety of economic, political, religious, family, gender and expressive institutions.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Religion in China 4R-OL-4C

Introduces students to China's "official" religions (Buddhism, Taoism, Islam, Protestantism, and Catholicism) and

the rich faith-based belief systems that are prominent in contemporary China (Shamanism, local deities, etc.).
(NOTE: Formerly Asian Religions and Philosophy)

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History since 1400 4R-OL-4C

Explores the history and interaction of major world regions since about 1400, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 231 Global Writing and Intercultural Communication 4R-OL-4C

Analyzes rhetorical traditions and communication styles within and across diverse cultures as well as global uses of English. Introduces students to theories and practices for communicating and collaborating across languages and cultures.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction's humanistic usefulness in examining human values from an "extra-species, extra-terrestrial" perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 243 Music History (Before 1650): Early European Music 4R OL 4C

Surveys the early music of Europe in the Medieval, Renaissance, and early Baroque periods and explores problems of accessing musical practices distant and distinct from our own.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS 324 Brazil Since 1500 4R-OL-4C

Provides a basic understanding of Brazilian history, major political parties and issues, geography, economy, and major social and cultural phenomena. Explores the creation of a multicultural society, Brazil's place in global systems, and other issues.

GS 327 Modern China 4R-OL-4C

Explores modern Chinese history from the Qing dynasty (1644-1911) to the present day.

GS 328 Pop Culture in China 4R-OL-4C

Examines the production and consumption of pop culture in China including literature, music, film, and print media.

GS 330 Contemporary Global Film 3R-3L-4C

Examines films outside of the Hollywood tradition with a consideration of the cultural, political, and economic influences that shape film.

GS331 Irish Drama 4R-OL-4C

Surveys Irish drama from about 1900 to the present.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple

perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 339 Contemporary Global Film 4R OL 4C

Surveys world cinema, emphasizing the importance of situating films within their historical and cultural background as well as recognizing the tensions between art and business in the film industry and how that shapes the medium.

GS 343 Musics of the World 4R OL 4C

Surveys the role of music in human cultures around the world and explores problems of accessing musical practices distant and distinct from our own, as well as thinking critically about those most familiar to us.

GS 350 International Trade and Globalization 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Prereq: SV 152 or SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Prereq: SV 151 or SV 152

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Tokyo 4R-OL-4C

Explores Tokyo from its origins to contemporary place as a "global capital" through history, geography, and culture.

GS 379 Japanese Culture 4R-OL-4C

Examines Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 380 Japanese Popular Culture 4R-OL-4C

Examines various aspects of Japanese popular culture including society, arts, history, education, and media.

GS 384 Japanese Society 4R-OL-4C

Introduces contemporary Japan from an anthropological perspective with an emphasis on the contradictions between hyper-modernity and traditionalism.

GS 386 Hispanic Culture and Civilization (Latin America) 4R-OL-4C Prerequisite: SP213 or permission of instructor

Introduces Hispanic culture and civilization from its origins to the present. Examines Hispanic Latin American societies through cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spanish Latin America. Taught in Spanish.

GS 387 Hispanic Culture and Civilization (Spain) 4R-OL-4C Prerequisite: SP213 or permission of instructor

Introduces Hispanic culture and civilization from its origins to the present. Examines Spanish society through cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spain. Taught in Spanish.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 413 Nazi Germany: Fact and Fiction 4R 0L 4C

Examines the history of Nazi Germany as well as its representation in literature, film, and new media.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS 425 Cities and Technology in the Industrial Age 4R-OL-4C

Explores development of cities and the machines and systems that make them possible as human life became more and more urban and industrial from 1700 to the present. Compares urban growth and city life in different parts of the world.

GS 429 Greek and Roman Drama 4R-OL-4C

Examines drama in the classical world with special emphasis on the ways it was produced, staged, and acted. Close reading of plays by the Greek and Roman dramatists in translation.

GS 430 World Drama 4R-OL-4C

Examines drama from multiple cultures and time periods through a thematic lens.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS 470 Japanese Media 4R-OL-4C

Explores historical and contemporary media-related Japanese culture, both in visual and text communications.

GS 480 Leadership & Global Challenges 4R 0L 4C Prereq: Junior or senior standing; cross listed with EMGT536

Examines the art of leadership and its development in our increasingly globalized society by studying general theoretical approaches, with close attention to the unique challenges which globalization and cross cultural interactions impose upon leaders.

GS 485 Seminar on Japanese Society 4R-OL-4C

Provides students a firm grounding in Western intellectual engagement with Japan, particularly from an

anthropological perspective. Considers how Japan has been created and framed as a site of study through close readings of relevant ethnographic literature.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

GS CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

IDEAS AND ARTS -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R OL 4C

Introduces the methods and subject matter of philosophy through examination of some of the major problems and figures in classical and contemporary philosophy, including the nature of reality, the existence of God, the criteria of knowing, the nature of mind, and the foundations of morality.

IA 102 Critical Thinking and Introduction to Logic 4R OL 4C

Introduces students to philosophical methodology for examining the truth of claims and the quality of arguments used to defend them, including informal logic, i.e., the study of arguments in natural language, as well as formal logic, i.e., the study of inference with purely formal content, for the purpose of clarifying thinking and improving reasoning.

IA 128 Introduction to Islam 4R-OL-4C

Introduces the major figures, tenets, and cultural adaptations of Islam from Muhammad to the present day.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Communicating STEM to a Public Audience 4R-OL-4C

Examines the role of scientists and engineers as public intellectuals who can influence policy and public understanding. Emphasizes strategies for communicating technical knowledge to public audiences through popular media.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 3R-3L-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Fundamentals of Tonal Music 4R OL 4C

Pursues the initial stages of literacy in western tonal music, from rhythm and pitch to basic functional harmonic analysis.

IA 299 Introduction to Theater Arts 4R-OL-4C

Explores the whole mechanism of the modern theater and how it works, including principles and theories of theatrical art: production, direction, acting, scenic design, costume design, lighting design, makeup, sound and multimedia, and theater architecture.

IA 301 Philosophy of Mind 4R OL 4C

Focuses on the philosophical investigation of the nature of the mind, its relationship to the brain/body, the phenomenon known as consciousness, and a host of related issues including freedom of the will and its implications for moral responsibility, the relationship between philosophy, psychology, and neuroscience, the nature of self and personal identity, the possibility of machine and animal consciousness, and the idea of mental disorder.

IA 302 Philosophy of Religion 4R OL 4C

Examines the nature and existence of God and religious experience, the meaning of religious language, and the relationship between religion, science, and philosophy through analysis of classical and contemporary texts and teachings of major figures in theology and philosophy.

IA 303 Political Philosophy 4R OL 4C

Examines the philosophical foundations of social and political organization, governance, rights, liberty, law, individualism, and justice. This course explores fundamental questions about organized society by engaging with classical and contemporary texts dealing with the state of nature, the idea of a social contract and its opposition, democracy and its ideals, virtues, and difficulties, human rights and liberties, alternatives to democracy including communism and communitarianism, and feminist and individualist theories.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 325 Islam and Muslim Groups in China 4R-OL-4C

Examines the localization of Islam among China's ten officially recognized Muslim ethno-national groups.

IA 328 Ethnicity & the State in China 4R-OL-4C

Introduces students to the concepts of ethnic group, ethnicity, and nationalism and explores how ethnonational identity is institutionalized, constructed, and negotiated in contemporary China.

IA 330 Documentary Film 3R-3L-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 338 Medicine in Literature 4R-OL-4C

Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 340 Ethics in Human Communication 4R-OL-4C

Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 342 Modern Southern Fiction 4R OL 4C

Examines the major writers of the American South (both the modern and contemporary periods). Emphasizes recurrent social themes and fictional methods.

IA 343 Visual Rhetoric and Graphic Novels 4R-OL-4C

Explores the relationships between art and argument in comic books and graphic novels. Provides a vocabulary for students to discuss, analyze, and produce graphic communication, including the creation of their own mini-comic. (No drawing skills required).

IA 344 Writing in a Digital Age 4R-OL-4C

Examines the influence of digital technologies on the ways we read, produce texts, and interact. Emphasizes strategies for producing new media texts, such as podcasts, blogs, infographics, and “viral” videos.

IA 346 Music Theory II: Basic Form and Composition 4R-OL-4C Prereq: IA246 or consent of instructor

Explores intermediate topics in western tonal music and applies theoretical concepts to music composition. Forms studied and composed include simple classical and popular music genres.

IA 348 Music Performance 1R-OL-1R Prereq: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C S Prereq: SV 150 or SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C W Prereq: SV 151 or SV 152

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Prereq: SV 150 or SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C S (even years) Prereq: SV 150 or SV 151 or SV 152

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 371 Cognitive Psychology 4R OL 4C

Explores how the mind works using experimental findings and psychological models. Topics include perception, attention, memory, reasoning, decision making, and language.

IA 380 Literature and Human Rights in Latin America 4R-OL-4C

Explores testimonial narratives, which give a “voice to the voiceless,” allowing marginalized peoples to bear witness to human rights abuses. Examines testimonial narratives in terms of historical context, structure, narrative voice, and effectiveness in addressing situations of oppression and violence. Taught in English.

IA 388 Food, Culture, and the Self 4R-OL-4C

Examines food as a focus for deeper inquiry into culture, identity, national development, globalization and social change.

IA 389 Anthropology of Addiction 4R-OL-4C

Examines the concept of addiction – a frequently used yet rather imprecise term -- from a variety of perspectives to better understand this complex term and cultural concept.

IA 401 Philosophy of Science 4R OL 4C

Examines a range of philosophical questions about the methods, foundations, assumptions, and scope of science, including: How does science work? Can science reveal truths about the structure of the world? What is the scientific method and how is it different from other forms of knowledge acquisition, such as philosophy? What is a scientific explanation? What counts as evidence for a theory? What are scientific laws? These and other questions will be explored by engaging with a variety of classical and contemporary philosophical texts and arguments.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global

environment.

IA 471 Computational Psychology 4R-OL-4C Pre: MA 381 or Consent of Instructor

Explores computational principles that can be used to explain human learning and develop intelligent machines. Includes programming assignments.

IA CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

SOCIETY AND VALUES -- Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 130 Introduction to Disability Studies 4R-OL-4C

Introduces disability studies, a multi-disciplinary field that identifies, challenges, and re-conceptualizes representations of disability. Topics may include disability history and policy, activism, bioethics, and the role of technology and engineering in our perceptions of disability.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 150 Introduction to Microeconomics 4R-OL-4C F,W,S

Analyzes the market behavior of buyers and sellers. Topics include demand and supply, costs, competition, oligopoly, monopoly, economic efficiency and resource allocation, the effects of government intervention, and international trade. A student cannot take both SV 150 and SV 151, Principles of Economics, for credit.

SV 152 Introduction to Macroeconomics 4R-OL-4C F,W,S

Analyzes the performance of the entire economy. Topics include demand and supply, GDP, unemployment and inflation, the impact of monetary and fiscal policy, business cycles, determinants of economic growth, and international finance. A student cannot take both SV 152 and SV 151, Principles of Economics, for credit.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Introduction to Psychology 4R-OL-4C

A broad survey of the scientific study of mind and behavior. Topics include learning, perception, emotion, motivation, memory, childhood development, personality, social behavior, and psychological disorders.

SV 188 Introduction to Sociology 4R-OL-4C

Examines the foundations of sociology, paying particular attention to how humans shape and give meaning to the world in which we live.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV244 Western Music in the Baroque, Classical, Romantic Eras 4R-OL-4C

Surveys composers, events, and genres of western art music in the “common practice period” and their contexts in world history.

SV245 Western Music in the 20th Century 4R-OL-4C

Surveys composers, events, and genres in the Modern and Postmodern periods and their contexts in world history.

SV246 Popular Music in the Era of Recorded Sound 4R-OL-4C

Surveys the impact of audio recording revolutions of the 20th century on American popular music and explores relationships between technology and its competing and complementary human interests, such as aesthetics, politics, tradition, commerce, law, ethics, among many others.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R OL 4C

Examines the ethical issues faced by professional businesspeople and engineers working in a global corporate context. Issues include the development and use of codes of professional ethics, the social responsibilities of corporations, the autonomy of professionals, whistleblowing and corporate loyalty, environmental obligations of corporations and professionals, standards of conduct in international business, and the impact of technology on our world.

SV 304 Bioethics 4R OL 4C

Examines the major moral issues in the development and practice of biomedicine and biomedical research through the analysis of philosophical and ethical theory as well as analysis of real cases of morally questionable practice in biomedicine. Topics include the autonomy and rights of patients, physicians, and researchers, informed consent and experimentation with humans and animals, the moral status of genetic and reproductive controls and interventions, the extension and termination of life, and the allocation of scarce medical resources.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect

with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 340 American Drama 4R-OL-4C

Surveys American drama from the colonial period to the present.

SV 341 African-American Drama 4R-OL-4C

Surveys African-American drama from the early 19th century to the present.

SV 342 Modern European Drama 4R-OL-4C

Surveys modern European drama from about 1870 to the present.

SV 345 Presidential Election Rhetoric 4R-OL-4C

Increases students' awareness and understanding of the U.S. Presidential election process, candidates, campaign issues, campaign advertising, debates, and the role of the news media. Focuses on analyzing and producing rhetoric associated with presidential campaigns.

SV 351 Managerial Economics 4R-OL-4C Prereq: SV 150 or SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. Students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Prereq: SV 151 or SV 152

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Prereq: SV 150 or SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 371 Social Psychology 4R OL 4C

Explores how people's behavior, feelings, and thoughts are influenced by their social environments. Topics include attitude formation, prejudice, relationships, group behavior, conformity, altruism, and aggression.

SV 373 Abnormal Psychology 4R-OL-4C

Explores the diagnosis, causes, and treatments of psychological disorders.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and evolution, the fossil record, and genetics; compares human behavior with other primates; and explores the extent and causes of human physical diversity.

SV 389 Anthropology of Sports 4R-OL-4C

Introduces the study of sport through a critical anthropological lens. Sport is used to contextualize gender, health, technology, ethnic difference, nationalism, sexuality, and socioeconomic class.

SV 402 Human Nature 4R OL 4C

Examines what it means to be human by examining major philosophical texts in the Western tradition in conjunction with recent developments in psychology and cognitive science. The central issues include happiness and the good life, morality, justice, and the structure of human social institutions.

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C F (odd years) Prereq: SV 150 or SV 151 or SV 152

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

SV 472 Studying Human Behavior 4R-OL-4C

Introduces students to the methods of behavioral science by having them design, run, and analyze actual psychology experiments.

SV CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

COMMUNICATION

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis of texts and images, research methods, and the conventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Prereq: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

SPECIAL TOPICS AND DIRECTED STUDY

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS

Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX456 Seminar for HSS Senior Project 2R-OL-2C F Prereq: Economics or International Studies major and Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX457 Directed Study for HSS Senior Project 2R-OL-2C Arranged Prereq: XX456 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double majors.

MODERN LANGUAGES

(NOTE: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Prereq: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Prereq: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Prereq: GE 213

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Prereq: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with

translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C

Summer Prereq: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Prereq: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-OL-4C S

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-OL-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

GS CPT / IA CPT / SV CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

HSS MAJORS

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

The IS major promotes the critical understanding of the historical and contemporary entanglements of diverse cultures around the world. It offers theoretical tools and models practical steps with which to assess competing claims about the world. Students will participate in the analysis of complex situations in which the evidence may be ambiguous and in which there may be no one clear answer. They will learn to devise questions that guide productive research into such situations.

Learning Outcomes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 - A. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 - B. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 - C. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.

- 2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 - A. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 - B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
- 3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 - A. Assemble and evaluate resources for research in international studies.
 - B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

1. **Disciplinary Distribution** (4 courses, 16 credit hours that introduce students to key concepts, disciplines, and analytical approaches in international studies).

Students choose one course each from **FOUR** of the following six disciplines. The courses have international processes, comparisons, or other connections as a central focus. They may be substituted with other courses with same focus with consent of IS major director.

Economics

- SV 150 Introduction to Microeconomics
- SV 152 Introduction to Macroeconomics

Geography

- GS 291 World Geography
- GS 491 Geography of Europe
- GS 492 Geography of Africa

Political Science

- GS 163 International Relations
- GS 161 Comparative Politics

Literature

- IA 233 World Literature
- IA 311 German Colonialism
- IA 380 Literature and Human Rights in Latin America

History

- GS 223 World History
- GS 422 Industrial Revolution in Global Context
- GS 221 Colonial Latin America

Anthropology

- GS 185 Introduction to Anthropology
- GS 128 Introduction to East Asia
- IA 328 Ethnicity and the State in China

2. **Concentration** (7 courses, 28 credit hours)

Each student must take seven courses that allow the student to develop advanced area or topic knowledge and disciplinary analytical skills in a coherent field of concentration. The student must choose these courses in consultation with the IS major director and other faculty, write a statement explaining how those courses fit together, and get it approved by a committee designated by the IS major director by the fall quarter of junior year.

- 3. **Language** (3 courses, 12 credit hours) One full year of a foreign language (e.g., German, Japanese, Spanish)
- 4. GS 496 and GS 497 **Senior Project** in International Studies (2 credits each; 4 credit hours total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

Senior project proposals will be approved by a committee designated by the International Studies Major Director.

HSS MINORS

MINOR IN ANTHROPOLOGY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

- 1. Five Courses in Anthropology
- 2. The following course is required:
 - GS 185 Introduction to Anthropology
- 3. Four additional courses from the list below:
 - GS 128 Introduction to East Asia
 - GS 368 Tokyo
 - GS 379 Japanese Popular Culture
 - GS 384 Japanese Society
 - GS 385 Japanese Society Seminar
 - IA 388 Food, Culture, and the Self
 - IA 389 Anthropology of Addiction
 - SV 386 Human Evolution
 - SV 389 Anthropology of Sports
 - XX 399 Special Topics
 - XX 499 Directed Study
- 4. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- 5. Substitutions may be made with the approval of the Minor Advisor

MINOR IN ART

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

- 1. Five Courses in Art
- 2. The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242 Visual Arts in Civilization
- 3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- 4. Substitutions may be made with the approval of the Minor Advisor

Courses

- GS442 Art History: Renaissance to Modern
- IA142 Drawing
- IA148 Beginning Photography
- IA244 Design and Color
- SV242 Visual Arts in Civilization

MINOR IN EAST ASIAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS128 Introduction to East Asian History
 - GS207 Asian Religions and Philosophy
 - GS327 Modern China
 - GS379 Japanese Popular Culture
 - GS368 Tokyo
 - GS380 Pop Culture in China
 - GS384 Japanese Society
 - GS385 Japanese Society Seminar
 - IA380 Islam and Muslim Groups in China
 - IA328 Ethnicity and State in China
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the minor advisor.

MINOR IN ECONOMICS

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Introduction to Microeconomics (SV 150);
 - b. Introduction to Macroeconomics (SV 152);
 - c. Intermediate Microeconomics (IA 350) or Intermediate Macroeconomics (IA 351);
 - d. Two additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor

Courses

- GS350 International Trade and Globalization
- GS351 International Finance
- GS352 Economic Growth and Development
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- IA352 Game Theory
- IA353 History of Economic Thought
- IA450 Mathematical Economics
- SV150 Introduction to Microeconomics
- SV152 Introduction to Macroeconomics
- SV351 Managerial Economics
- SV352 Money and Banking
- SV353 Industrial Organization
- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX456/457 Senior Project

MINOR IN EUROPEAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:

- GS313 Contemporary Spain
 - GS337 Shakespeare's Europe
 - GS363 European Politics and Government
 - GS366 The European Union
 - GS431 Literary London
 - GS469 Contemporary British Fiction and Film
 - GS491 Geography of Europe
 - IA311 Topics in German Culture I
 - IA337 European Romanticism
 - SV222 Western Civilization to 1500
 - SV223 Western Civilization from 1500 to the Present
 - SV291 Medieval Europe
 - SV413 Contemporary Germany
 - XX399 Special Topics
 - XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN GEOGRAPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

- 1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
- 2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- 3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS191 Geography of Middle East
- GS222 Modern Latin America
- GS291 World Geography
- GS327 Modern China
- GS391 Contemporary Europe
- GS491 Geography of Europe
- GS492 Geography of Africa
- SV191 Cultural Geography
- SV291 Medieval Europe
- XX399 Special Topics
- XX499 Directed Study

MINOR IN HISTORY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

- 1. Five courses in History
- 2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- 3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS221 Colonial Latin America
- GS223 World History since 1400
- GS222 Modern Latin America
- GS324 Brazil Since 1500
- GS325 Cities and Technology
- GS413 Nazi Germany: Fact and Fiction
- GS422 Industrial Revolution in Global Context
- SV222 Western Civilization to 1500
- SV223 Western Civilization since 1500
- SV322 Disasters and Modern Society since 1700
- XX399 Special Topics

- XX499 Directed Readings

MINOR IN LANGUAGE AND LITERATURE

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and RH 330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS237 Science Fiction
- GS334 Travel in World Literature
- GS335 The Global Novel in the Twentieth Century
- GS336 Literature of War
- GS337 Shakespeare's Europe
- GS338 Contemporary Arabic Literature in Translation
- GS339 Contemporary Global Film
- GS412 Topics in German Culture II
- GS431 Literary London
- GS432 Literature and Film of the Global Economy
- GS462 Postcolonial Literature
- GS469 Contemporary British Fiction and Film
- IA230 Fundamentals of Public Speaking
- IA231 Introduction to Poetry
- IA232 African American Music in American Literature
- IA233 World Literature
- IA234 Major American Writers
- IA235 Major British Writers
- IA237 Introduction to Drama
- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature
- IA337 European Romanticism
- IA338 Medicine in Literature
- IA339 Rebellion in American Literature
- IA341 Steinbeck and American Society
- IA342 Modern Southern Fiction
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Gender, Work & Popular Culture
- SV334 Utopian Thought and Literature
- SV336 Contemporary American Fiction
- SV337 20th century American Novel
- SV339 Literature and the Environment
- SV234 The American Dream
- XX399 Special Topics
- XX499 Directed Study

MINOR IN LATIN AMERICAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS221 Colonial Latin America
 - GS222 Modern Latin America
 - GS313 Contemporary Spain
 - GS324 Brazil Since 1500
 - IA332 Don Quixote
 - SV338 Latin American Fiction: The Boom and Beyond
 - XX399 Special Topics
 - XX499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN MODERN LANGUAGES (GERMAN, JAPANESE, AND SPANISH)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture
IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation
Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413
Japanese Language and Culture X/XI/XII

XX 399 Special Topics
XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.
Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

MINOR IN MUSIC

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. Twenty credits (the equivalent of five courses) in Music. IA246, IA346, SV244, and four credits of IA348 are

required.

2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Music Theory courses (*both required*):

- IA246 Music Theory I: Fundamentals of Tonal Music
 - IA346 Music Theory II: Basic Form and Composition (*pre-requisite: IA246*)
- Students who have taken music theory before attending Rose Hulman may choose to take a Theory I placement test in order to be granted admittance to Music Theory II. Students who successfully pursue this option must then substitute for Music Theory I another music related course, as approved by the Music Advisor.*

Music History and Culture courses (*one required; student may chose the other*):

- GS243 Early European Music (Before 1650)
- SV244 Western Music of the Baroque, Classical, and Romantic Eras (*required*)
- SV245 Western Music in the 20th Century
- SV246 Popular Music in the Era of Recorded Sound
- GS343 Musics of the World

Music Performance (*four credits required*):

- IA348 Music Performance (*pre requisite: consent of the ensemble director[s]*)
- One credit represents one academic term of satisfactory participation in one accredited Performing Groups (Concert Band, Jazz Ensemble, String Ensemble/Orchestra, and Chorus). Maximum of two credits (that is, participation in two ensembles) per term. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for "satisfactory participation" will be provided to the candidate by the ensemble directors.*

MINOR IN PHILOSOPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy has the following requirements:

1. Five courses in Philosophy, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Philosophy Courses:

- IA101 – Introduction to Philosophy
- IA102 – Critical Thinking & Introduction to Logic
- IA401 – Philosophy of Science
- IA302 – Philosophy of Religion
- IA301 – Philosophy of Mind
- IA303 – Political Philosophy
- SV402– Human Nature
- SV303 – Business & Engineering Ethics
- SV304 – Bioethics
- XX399 – Special Topics
- XX499 – Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
 2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
 3. Substitutions may be made with the approval of the Minor Advisor.
- Courses

- GS161 Comparative Politics
- GS163 International Relations
- GS361 Politics of the Global Economy
- GS366 The European Union
- SV166 American Politics and Government
- SV369 British Politics and Government
- IA463 Seminar on America's Future
- XX399 Special Topics
- XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Principles of Psychology (SV 171).
2. Four other psychology courses.
3. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
4. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
5. Substitutions may be made with the approval of the Minor Advisor.

Courses:

- SV 171 Principles of Psychology
- SV 372 Social Psychology
- SV 472 Studying Human Behavior
- SV 373 Abnormal Psychology
- IA 371 Cognitive Psychology
- IA 471 Computational Psychology
- IA 301 Philosophy of Mind

Minor in Theater and Drama

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

Requirements:

1. Five courses (20 credits) in Theater and Drama.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the minor advisor.

Courses:

- IA 299 Introduction to Theater Arts
- IA 237 Introduction to Drama
- IA 240 Introduction to Shakespeare
- SV 340 American Drama
- SV 341 African American Drama
- SV 342 Modern European Drama
- GS 337 Shakespeare's Europe
- GS 429 Greek and Roman Drama
- GS 430 World Drama

GERMAN TECHNICAL TRANSLATOR’S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute's degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60



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| Incoming Freshman | Community Members | Parents |

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Army ROTC (Military)

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

CURRICULUM

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College,

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

ADVANCED COURSE

Freshman Year

		Credit
MS 101	Leadership and Personal Development	1
MS 102	Introduction to Tactical Leadership	1
MS 103	Basic Tactical Leadership	1
		3

Sophomore Year

		Credit
MS 201	Innovative Team Leadership	2
MS 202	Foundations of Tactical Leadership	2
MS 203	Foundations of Tactical Leadership II	2
		6

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Summer

MS 206	ROTC Basic Camp	0
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Junior Year

		Credit
MS 301	Adaptive Team Leadership	4
MS 302	Leadership Under Fire	4
MS 303	Leadership Under Fire II	4
		12

Senior Year

		Credit
MS 401	Developing Adaptive Leaders	4
MS 402	Leadership in a Complex World	4
MS 403	Leadership in a Complex World II	4
		12

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training..



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Industry Partners
Trustees
Parents

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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose- Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

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- Army ROTC (Military)
- Pre-Professional Programs



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[Parents](#)

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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Air Force ROTC (Military)

LT Col Morgan III, CAPT Jeffers

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Prereq: None

This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Prereq: AS 101 or instructor permission

This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Prereq: AS 102 or instructor permission

This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Prereq: Enrollment in AS 101, AS 102, or AS 103

Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Prereq: AS 103 or instructor permission

This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Prereq: AS 201 or instructor permission

This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Prereq: AS 202 or instructor permission

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

This course is a continuation of the winter quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Prereq: Enrollment in AS 201, AS 202, or AS 203

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Prereq: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Prereq: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Prereq: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Prereq: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Prereq: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Prereq: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Prereq: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Prereq: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Army ROTC (Military)

LTC Eric Walthall and MSG Zoleske

FRESHMAN YEAR Basic Course

MS 101: Introduction to the Army and Critical Thinking 1R-3L-1C F Prereq: None

MS 101 introduces Cadets to the personal challenges and competencies that are critical for effective leadership. Cadets learn how the personal development of life skills such as critical thinking, time management, goal setting, stress management, and comprehensive fitness relate to leadership, and the Army profession.

MS 102: Adaptive Leadership and Professional Competence 1R-3L-1C W Prereq: MS 101 or Instructor Permission

MS 102 introduces Cadets to the personal challenges and competencies that are critical for adaptive leadership. Cadets learn the basics of the communications process and the importance for leaders to develop the essential skills to effectively communicate in the Army. Students will examine the Army Profession and what it means to be a professional in the U.S. Army.

MS 103: Basic Tactical leadership 1R-3L-1C S Prereq: MS 101 and 102 or Instructor Permission

MS 103 continues the exploration of leadership fundamentals and examines the leadership process as affected by individual differences and styles, group dynamics, and personality behavior of leaders. Students will experience an introduction of fundamental leadership concepts, and examine factors that influence leader and group effectiveness. Students will fully explore the basic soldier skills and squad level tactical operations. Students participate in briefings and hands-on practical exercises. Attention is devoted to development of leadership potential through practical exercises both in and out of the classroom.

SOPHOMORE YEAR Basic Course

MS 201: Leadership and Decision Making 2R-3L-2C F Prereq: MS 101, 102, and 103 or Instructor Permission

MS 201 explores the dimensions of creative and innovative tactical leadership strategies and styles by examining team dynamics and two historical leadership theories that form the basis of the Army leadership framework. Aspects of personal motivation and team building are practiced planning, executing and assessing team exercises.

MS 202: Army Doctrine and Team Development 2R-3L-2C W Prereq: MS 201 or Instructor Permission

MS 202 examines the challenges of leading teams in the complex operational environment. The course highlights dimensions of terrain analysis, patrolling, and operation orders. Further study of the theoretical basis of the Army Leadership Requirements Model explores the dynamics of adaptive leadership in the context of military operations. Cadets develop greater self awareness as they assess their own leadership styles and practice communication and team building skills.

MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Prereq: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Cadet Initial Entry Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Cadet Initial Entry Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

JUNIOR YEAR Advanced Course

MS 301: Training Management and the Warfighting Functions 3R-3L-4C F Prereq: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 Cadets will study, practice, and apply the fundamentals of Army Leadership, Officership, Army Values and Ethics, Personal Development, and small unit tactics at the platoon level. At the conclusion of this course, Cadets will be capable of planning, coordinating, navigating, motivating and leading a squad and platoon in the execution of a mission during a classroom PE, a Leadership Lab, or during a Leader Training Exercise (LTX).

MS 302: Applied Leadership in Small Unit Operations 3R-3L-4C W Prereq: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when under fire are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Cadet Leader Course (CLC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Prereq: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for CLC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

Overview of CLC: Cadet Leader Course

Summer Term Only

The purpose of the course is to train U.S. Army ROTC Cadets to Army standards, to develop their leadership skills, and to evaluate their officer potential. The 29-day course starts with individual training and leads to collective training, building from simple to complex tasks. This building-block approach permits integration of previously-learned skills into follow-on training. This logical, common-sense training sequence is maintained for each training cycle. Every day at CLC is a day of training.

SENIOR YEAR- Advanced Course

MS 401: Mission Command and Ethics 3R-3L-4C F Prereq: MS 303

MS 401 is an advanced course that places primary emphasis on Officership with our MS IV cadets who are our educational main effort; MS 401 and 402 together refine and ultimately completes the Cadet-to commissioned officer transition. In MS 401 Mission Command and ethics is stressed in order to assist the Cadet in further embracing their future role as an Army officer.

MS 402: Mission Command and the Army 3R-3L-4C W Prereq: MS 401

MS 402 and MS 403 are the culmination of a four-year sequential, progressive, challenging developmental leadership experience. It is during this quarter and MSL 403 that the Cadet is undergoing final preparation for the duties and responsibilities of a commissioned officer along with their integration into the Army. The emphasis is placed on critical knowledge, skills, abilities and competencies skills newly commissioned officers will need to succeed in their first unit of assignment, and the modern operating environment where they will be expected to plan, prepare, execute, and assess platoon-level training strategies and more to enable mission accomplishment.

MS 403: Leadership in a Complex World II 3R-3L-4C S Prereq: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

MS 497: Military Science Independent Study Variable Credit Prereq: MS 301, 302, 303 and Instructor Permission

MS 497 provides ROTC cadets who have completed their Cadet Leader Course the opportunity to conduct detailed research and independent study on a current problem or topic associated with the military. Program of study will be arranged individually with the Professor of Military Science.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies

and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biology & Biomedical Engineering

Biology and Biomedical Engineering Faculty: Ahmed, Anthony, Buckley, Chiu, Coppinger, Dee, Dosmar, Hill, Ingram, Livesay, O'Connor, Rogge, and Weiner.

Biology

BIO 101 Essential Biology 4R-OL-4C F,W,S Prereq: None

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed BIO110, BIO120 or BIO130 cannot receive credit for taking BIO101.

BIO 102 Nutrition 4R-OL-4C W Prereq: None

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for BIO or BE majors and not as an BIO elective.

BIO 110 Cell Structure and Function 3R-3L-4C F,S Prereq: None

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

BIO 120 Comparative Anatomy & Physiology 3R-3L-4C W Prereq: None

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

BIO 130 Evolution and Diversity 3R-3L-4C S Prereq: None

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

BIO 191 Special Topics in Biology XR-OL-XC Arranged Prereq: Consent of instructor

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed BIO course.

BIO 205 Cellular Physiology 4R-OL-4C F Prereq: BIO 110

The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for BIO205 cannot earn credit for BIO210 or BIO230 without departmental consent.

BIO 210 Mendelian and Molecular Genetics 3R-3L-4C F Prereq: BIO 110 or instructor consent

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

BIO 220 Microbiology 3R-3L-4C W Prereq: BIO 110 or instructor consent

Discusses the essential properties of eubacteria and archaea. Bacterial nutrition, growth, genetics and structural

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

https://www.rose-hulman.edu/course-catalog/course-catalog-2016-2017/course-descriptions/biology-biomedical-engineering.aspx[1/20/2017 12:17:02 PM]

and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

BIO 230 Cell Biology 3R-3L-4C S Prereq: BIO 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

BIO 310 Plant Structure & Function 3R-3L-4C S Prereq: BIO 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

BIO 320 Ecology 3R-3L-4C F Prereq: BIO 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

BIO 330 Evolutionary Biology 4R-0L-4C W Prereq: BIO 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

BIO 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Prereq: BIO 120, and Jr/Sr standing or consent of instructor

Designed to introduce biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

BIO 350 Principles of Synthetic Biology (2R-0L-2C) W Prereq: none

Open to all majors. This course covers the biological foundations of synthetic biology. It is directed at understanding how biological information is stored and processed, and how it is expressed as biological function. Particular attention will be paid to how the expression of this information is regulated and how cells can be engineered to solve contemporary problems in health, energy, manufacturing and sustainability.

BIO 351 Synthetic Biology Design (2R-0L-2C) S Prereq: BIO 350

Open to all majors. This course focuses on the design of novel biological parts, devices and systems, and their use in engineering cell function. Bioengineering principles and the design of genetic logic circuits, memory modules, biosensors and other cellular devices will be addressed. For the final project, students will design a novel biological system that meets the standards and goals of the International Genetically Engineered Machine Competition.

BIO 352 Synthetic Biology Laboratory (studio format, 4 days x 3 hrs, 4C) Su1 Prereq: Instructor Consent

Open to all majors. This project-based studio laboratory course focuses on the fundamental laboratory techniques employed in the synthetic biology laboratory. Relevant background and theory will be discussed and applied in the hands-on learning of core laboratory techniques. In practice, students will build and test novel genetic devices designed to advance the current International Genetically Engineered Machine Competition (iGEM) Team project. Significant contribution to the project will earn students membership on the Rose-Hulman iGEM team and attribution in iGEM competition materials.

BIO 399 Practice of Science 4R-0L-4C Prereq: RH 330 and MA 223, or consent of instructor

This course focuses on skills required for implementing scientific research, including reading the primary literature, experimental design, scientific writing, oral presentations, research proposal writing, poster presentations, and investigation of research programs (through seminars or individual meetings). Each student chooses a project and research mentor by the end of the course.

BIO 410 Infection and Immunity 4R-0L-4C Arranged Prereq: BIO 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

BIO 411 Genetic Engineering 4R-0L-4C Arranged Prereq: BIO 205 or BIO 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

BIO 421 Applied Microbiology 4R-0L-4C Arranged Prereq: BIO 110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of

chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

BIO 431 Genomics and Proteomics 4R-0L-4C S Prereq: BIO 205 or BIO 210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

BIO 441 Virology 3R-3L-4C Prereq: BIO 110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

BIO 451 Cancer Biology 4R-0L-4C Prereq: BIO 205 or BIO 210 or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

BIO 461 Evolutionary Medicine 4R-0L-4C Arranged Prereq: BIO 130, and BIO 205 or BIO 210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

BIO 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged

Prereq: BIO 205 or BIO 210 or consent of instructor

Strategies and methods used to identify and understand the genetic and molecular bases of inherited human disease are addressed. Topics include, human population genetics, pedigrees, genetic and physical mapping of human genes, linkage analysis, and diagnostic testing. Primary literature is routinely utilized.

BIO 491 Special Topics in Biology XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed BIO course.

BIO 492 Directed Study in Biology XR-XL-XC Arranged Prereq: Consent of instructor

Covers biology material of mutual interest to the student and instructor which cannot be experienced in any other listed BIO course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the BBE department is required to use this course to fulfill BIO elective credit requirements.

BIO 496 Senior Thesis Research I 0R-6L-2C F,W,S Prereq: BIO 399 and consent of instructor

Initiation of senior thesis under the direction of an BBE faculty mentor. Major tasks include creation and submission of a research proposal and piloting procedures. Additional requirements for adequate progress determined by each faculty mentor.

BIO 497 Senior Thesis Research II 0R-12L-4C F,W,S Prereq: BIO 399 and consent of instructor

Continuation of research under the direction of an BBE faculty mentor. Major tasks include data acquisition and methodological refinement. Additional requirements for adequate progress determined by each faculty mentor.

BIO 498 Senior Thesis Research III 0R-12L-4C F,W,S Prereq: BIO 399 and consent of instructor

Continuation of research under the direction of an BBE faculty mentor. Major tasks include data acquisition and preliminary analysis. Additional requirements for adequate progress determined by each faculty mentor.

BIO 499 Senior Thesis Research IV 0R-6L-2C W Prereq: BIO 399 and consent of instructor

Completion of senior thesis under the direction of an BBE faculty mentor. Major tasks include final analysis, public presentation of results, and submission of the written thesis. Additional requirements for adequate progress determined by each faculty mentor.

BIO CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of

employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4C S Prereq: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE 201 Biomedical Instrumentation and Measurements 3R-3L-4C W, S Prereq: BE 100, ES 203

Discussion of measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors (temperature, force, pressure, velocity, etc), and basics of microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I 3R-3L-4C W Prereq: BIO 120, BIO 205

An analysis of neural, muscular, and endocrine physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Prereq: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of cradle to cradle design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II 3R-3L-4C S Prereq: BE310

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3C W Prereq: ES 201, EM 204, and BE 201, or consent of instructor Co: BE 351 or BE352, and BE 361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Signal Processing 3R-3L-4C F Prereq: BE 201, ES 203

This course introduces the fundamental of biomedical signal processing strategies. Topics include data acquisition, A/D and D/A conversion, digital filter design, time-frequency analysis, and I/O interfaces. Multichannel data processing and high dimensional data analysis techniques are also covered. Lectures will be accompanied by data analysis assignments and projects using MATLAB, LabVIEW, and microcontrollers.

BE 350 Biocontrol Systems 4R-0L-4C Prereq: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE 351 Biomedical Engineering Lab 1R-3L-2C Coreq: BE 331 and BE 361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE 352 Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE 331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 353 Biomaterials Lab 0R-3L-1C Prereq: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE 361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard

testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 385 Quality Methods 4R-0L-4C S Prereq: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (Pcharts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as MA 385

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Prereq: BE 201, Coreq: EM 204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 400 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Prereq: BE 390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Prereq: BE 410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Prereq: BE 420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 482 Bioengineering Statistics 4R-0L-4C Prereq: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Prereq: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F,W,S Prereq: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing 3R-3L-4C W Prereq: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Analysis of Physiological Systems I 3R-3L-4C W Prereq: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Analysis of Physiological Systems II 3R-3L-4C S Prereq: Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 520 Introduction to Brain Machine Interfaces 3R-3L-4C S Prereq: BE340 or ECE480

This course is an introduction to the basics of motor cortical functions related to voluntary and imagery movements, evoked response potentials, invasive vs. noninvasive electrode design considerations, quantitative EEG analysis techniques used in clinical settings, and the applications of brain-machine interfaces/brain-computer interfaces in the restoration of mobility, communication and motor function.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Prereq: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Prereq: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3 R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535 Biomedical Optics 4R-0L-4C W Prereq: PH 113, MA 212, and SR standing or GR standing

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 435 and OE 535. Cross-listed with OE 535.

BE 539 Multiscale Biomechanics 3R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and BE340, or BE340 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as ECE584.

BE 543 Neuroprosthetics 3R-3L-4C Prereq: BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Prereq: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Prereq: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Prereq: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Prereq: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 565 Experimental Methods in Tissue-Biomaterial Interactions 3R-3L-4C S Prereq: BE 361, or consent of instructor

This course focuses on teaching students experimental methods used for investigations of tissue-biomaterial interactions. Topics include bioethics issues associated with experiments on cells, tissues, animals, and people; biosafety issues associated with cells/tissues from animals and humans; the design, critique, and statistical analysis of experiments. Students conduct hands-on investigations of cell-biomaterial interactions which require the use of common laboratory equipment, aseptic technique, mammalian cell culture, and current molecular methods to investigate cell viability, structure, and function.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Prereq: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 Selected Topics F,W,S

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.

BE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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electives also provides biomathematics students with an opportunity to apply knowledge gained through BMTH coursework. The following focus areas are illustrative examples to consider.

Applied Mathematics

BE 350	Biocontrol Systems
MA 275/375	Discrete and Combinatorial Algebra I/II
MA 332	Intro. to Computational Science [required for major]
MA 330	Vector Calculus
MA 342	Computational Modelings
MA 366	Real Analysis
MA 367	Functions of a Complex Variable
MA 436	Introduction to Partial Differential Equations
MA 472	Graph Theory
MA 491	Introduction to Mathematical Modeling

Biochemistry

BMTH 312	Bioinformatics
BMTH 310	Mathematical Biology
CHEM 251/252/253	Organic Chemistry I/II/III
CHEM 326	Bioanalytical Chemistry
CHEM 330/331	Biochemistry I/II
CHEM 430	Advanced Biochemistry

Bioinformatics & Biostatistics

BMTH 312	Bioinformatics
MA 381	Intro. to Probability with Statistics [required for major]
MA 382	Intro. to Statistics with Probability
MA 382	Engineering Statistics II
MA 386	Statistical Programming
MA 482	Bioengineering Statistics

Biomechanics

BE 361	Biomaterials
BE 525	Biomedical Fluid Mechanics
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopedic Biomechanics

Biophysics

PH 302	Biophysics
BE 525	Biomedical Fluid Mechanics

Cellular and Molecular Biology

BIO 220/230	Prokaryotic/Eukaryotic Cell and Molecular Biology [required for major]
BIO 205	Cellular Physiology
BIO 411	Genetic Engineering
BIO 421	Applied Microbiology
BIO 431	Genomics and Proteomics
BMTH 310	Mathematical Biology
CHEM 455	Natural Products [offered irregularly]

Computational Biology

BMTH 310	Mathematical Biology
BMTH 413	Computational Biology
CSSE 220	Object Oriented Software Development
CSSE 333	Database Systems
CSSE 403	Programming Language Paradigms
CSSE 431	Artificial Intelligence
MA/CS 335	Introduction to Parallel Computing
MA 342	Computational Modeling
MA 433	Numerical Analysis
MA 435	Finite Difference Methods
MA/CS 473	Design and Analysis of Algorithms

Ecology

BIO 130	Evolution and Diversity
BIO 264	Introduction to Environmental Science
BIO 320	Ecology
BMTH 310	Mathematical Biology
CHEM 371	Environmental Analytical Chemistry

Epidemiology & Pathology

BE 310/320	Analysis of Physiological Systems I/II
BIO 410	Infection and Immunity
BIO 441	Virology
BIO 451	Cancer Biology
BIO 461	Evolutionary Medicine
BIO 471	Genetic and Molecular Analysis of Inherited Human Disease
BMTH 310	Mathematical Biology

Evolution

BIO 130	Evolution and Diversity
BIO 330	Evolutionary Biology
BIO 461	Evolutionary Medicine
SV 386	Human Evolution

Imaging and Optics

BE 435	Biomedical Optics
ECE 480	Introduction to Image Processing
BE 541	Medical Imaging Systems
MA 429	Mathematical Methods of Image Processing
PH 302	Biophysics

Medicine

BIO 120	Comparative Anatomy and Physiology
BIO 410	Infection and Immunity
BIO 441	Virology
BIO 451	Cancer Biology
BIO 461	Evolutionary Medicine
BIO 471	Genetic and Molecular Analysis of Inherited Human Disease
BE 541	Medical Imaging Systems
CHEM 251/252/253	Organic Chemistry I/II/III
CHEM 330/331	Biochemistry I/II
CHEM 420	Advanced Biochemistry

Physiology

BIO 120	Comparative Anatomy and Physiology
BIO 205	Cellular Physiology
BE 310/320	Analysis of Physiological Systems I & II
BE 520	Introduction to Brain Machine Interfaces



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Academics

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Chemical Engineering

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CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Prereq: None
An introduction to problem solving and structured programming concepts using spreadsheets and computational software. Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations.

CHE 200 Career Preparation I 1R-0L-0C F Prereq: sophomore standing in Chemical Engineering
Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F Prereq: CHEM 113 or concurrent registration in CHEM 112, MA 113, and PH 111
An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Prereq: CHE 201, MA211
The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Prereq: CHE 201, MA211
Physical properties of fluids, fluid statics, laminar and turbulent flow. Design of pipe networks and pumps. Fluid flow as momentum transport. Flow through porous media. Non-Newtonian fluid flow. Flow past objects and boundary layer concept. Emphasis is placed on general methods of analysis applicable to any fluid.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Prereq: CHE 202, MA 211 Coreq: CHE 110
First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F,W Prereq: CHE 303, MA 212
Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Study of phase equilibria involving the use of a process simulator.

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Prereq: CHE 110, MA 211, MA 212 or concurrent enrollment
The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression

- Air Force ROTC (Military)
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- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Prereq: CHEM 115 or consent of instructor

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Prereq: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304

Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Prereq: CHE 320, CHE 304

Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Prereq: CHEM 360 and CHE 304

The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Prereq: Senior Standing in Chemical Engineering

Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Prereq: CHE 321, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Prereq: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Prereq: CHE 321

Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Prereq: CHE 416, CHE 404

Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Prereq: CHE 417 or consent of instructor

Completion of an open-ended design project that will include written and oral communication of intermediate results and a final written report.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W Prereq: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F Prereq: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 460 Particle Technology 4R-0L-4C Prereq: MA 212, CHE 202, CHE 301

Introduction to the fundamentals of particle technology including particle characterization, transport, sampling, and processing. Students will learn about the basic design and scale-up of some industrial particulate systems (including fluidized beds, mixers, pneumatic conveying systems, cyclone separators, and hoppers) as well as environmental and safety issues related to particulate handling.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Prereq: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Prereq: CHE 303 or CHEM361 or CE205 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S Prereq: CHE303

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F,W,S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F,W,S Prereq: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

CHE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

CHE 502 Transport Phenomena 4R-0L-4C Prereq: CHE320

Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows

will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W Pre: CHE 321 or consent of instructor

Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 515 Nanomaterials Science and Engineering 4R-0L-4C Prereq: CHE 315 or ME 328

Current research trends and industrial activity in the field of nanotechnology. Contains an overview of nanoscale characterization and production methods and emphasizes the roles that chemical functionality, thermodynamics, and physics play in determining the unique properties of nanoscale materials systems. Independent student reviews of current research literature form an integral part of the course.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 511, ME 519, and ECE 519.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: BIO110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: BIO110, CHE 321 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the

requirements of the M.S. degree.



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Course Descriptions

Minors

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Graduate Studies

CATALOG HOME

Chemistry and Biochemistry

Professors Allison, Brandt, R. DeVasher, Erwin, Hoffman, Morris, Mottel, Mueller, Tilstra, Weatherman and Wilson.

CHEM 111 General Chemistry I 3R-3L-3C F,W,S Prereq: None; Coreq: CHEM111L
Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 111L General Chemistry I Laboratory 0R-3L-1C F,W,S Prereq: None; Coreq: CHEM 111
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM111 recitation.

CHEM 112 Chemistry Honors 4R-3L-5C F Prereq: Advanced placement
An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-3C W,S Prereq: CHEM 111 and CHEM 111L; Coreq: CHEM 113L
Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 113L General Chemistry II Laboratory 0R-3L-1C W,S Prereq: CHEM 111 and CHEM 111L; Coreq: CHEM 113
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 115 General Chemistry III 3R-3L-3C W,S Prereq: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 115L
Topics in this course include acid-base reactions, electrochemistry, and coordination chemistry.

CHEM 115L General Chemistry III Laboratory 0R-3L-1C W,S Prereq: CHEM 113 and CHEM 113L or CHEM 112; Coreq: CHEM 115
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 200 Career Preparation 1R-0L-1C W
This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with MA200, and SV200.

CHEM 225 Analytical Chemistry 3R-3L-3C F, S Prereq: CHEM 115 and CHEM 115L; Coreq: CHEM 225L
This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate

- Air Force ROTC (Military)
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- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 225L Analytical Chemistry Laboratory 0R-3L-1C F, S Prereq: CHEM 115 and CHEM 115L; Coreq: CHEM 225

This course represents the laboratory component of analytical chemistry. Practicums are part of the grade along with reports.

CHEM 251 Organic Chemistry I 3R-0L-3C F Pre: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 251L

An introduction to the classification of organic compounds, their structural features, including stereochemistry, and concepts related to reaction mechanisms and synthetic methods.

CHEM 251L Organic Chemistry I Laboratory 0R-3L-1C F Prereq: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 251

Organic Laboratory techniques are developed along with appropriate spectroscopic methods. Assessment is in part via practicums. Computational chemistry methods and green chemistry approaches are also introduced.

CHEM 252 Organic Chemistry II 3R-0L-3C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252L

Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis, and an introduction to the methods used to determine structure, including IR and NMR spectroscopy and mass spectrometry.

CHEM 252L Organic Chemistry II Laboratory 0R-3L-1C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252

A continuation of CHEM251L where additional, more complicated synthetic techniques and methods along with additional spectroscopic techniques are introduced. Assessment is in part via practicums.

CHEM 253 Organic Chemistry III 3R-0L-3C S Prereq: CHEM 252 and CHEM 252L; Coreq: CHEM 253L

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 253L Organic Chemistry III Laboratory 0R-4L-1C S Prereq: CHEM 252 and CHEM 252L; Coreq: CHEM 253

Project based laboratory where techniques and skills developed in the previous organic laboratories are applied to more open-ended problems.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Prereq: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Prereq: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research performed under the direction of a faculty member selected by mutual agreement. This course is designed for research performed before taking CHEM291. Students may register for 1 to 2 credit hours per quarter.

CHEM 291 Introduction to Chemical Research 2R-4L-3C W Prereq: CHEM 113/113L, or 112

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members and be required to attend all seminars during the quarter.

CHEM 304 Glassblowing 1R-3L-1C S Prereq: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Prereq: CHEM 225 and CHEM 225L

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Prereq: CHEM 225 and CHEM 225L

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Prereq: CHEM 252

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Prereq: CHEM 330 and BIO 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C W, S Prereq: CHE 303, CHE 304, and CHEM 115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Prereq: CHEM 115, CHEM 115L, MA212 and MA 381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Prereq: CHEM 111, CHEM 111L, MA 212, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 391 Research Proposal 1R-0L-1C F,W,S Prereq: CHEM 291, RH 330; Coreq: CHEM 490

Students will take online lessons related to the generation and communication of research ideas culminating in the production of a research proposal. The research proposal will be written under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 395 Chemistry Seminar 0R-0L-0C F Prereq: None

Students will be required to attend and/or present research seminars, the number to be determined by the department. The students will register for the course in the fall of the third year and if all the requirements are met, the students will receive a grade of Satisfactory. Failure to meet the requirements during the fall quarter will result in No Grade and the student must complete the requirements by the end of the third year. If the requirements are not completed by the end of the third year, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 433 Biochemistry Laboratory 0R-3L-1C S Prereq: CHEM 330

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Prereq: CHEM252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Prereq: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 451 Organic Structure Determination 2R-8L-4C S Prereq: CHEM 253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Prereq: CHEM 251 or CE 564 or consent of instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor
Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F,W,S Prereq: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.

Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: Permission of instructor

Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Prereq: CHEM 291

Research performed under the direction of a faculty member selected by mutual agreement. Students may register for 1 to 3 credit hours per quarter.

CHEM 491 Research Thesis 1R-0L-1C F,W,S Prereq: CHEM 490

Students will publish a thesis on their undergraduate research. The thesis will be written under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 495 Chemistry Seminar 0R-0L-0C F Prereq: None

Students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 496 Chemistry Seminar 0R-0L-0C W Prereq: None

Students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 497 Research Presentation 1R-0L-1C F W S Prereq: CHEM 490

Students will deliver a professional seminar on their undergraduate research. A student must have at least three credit hours of CHEM490. The seminar will be prepared under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 530 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules. Students enrolled in CHEM 530 must complete a project not covered in CHEM 430. A student may not receive credit for both CHEM 430 and CHEM 530.

CHEM 531 Biochemical Instrumentation 3R-4L-4C Prereq: BIO 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 532 Biochemical Pharmacology 4R-0L-4C Prereq: CHEM 330

Topics include medicinal chemistry and molecular pharmacology. The topics will also include a survey of potential drug targets, the molecular interactions between drugs and their targets, the drug discovery and development process and case studies of drugs treating diseases such as cancer, bacterial and viral infection, and neurological disorders.

CHEM 545 Organometallic Chemistry 4R-0L-4C Prereq: CHEM 115, CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 552 Synthetic Organic Chemistry 4R-0L-4C Prereq: CHEM 253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 554 Theoretical Organic Chemistry 4R-0L-4C Prereq: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 555 Natural Products 4R-0L-4C Prereq: CHEM 253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 557 Synthetic Polymer Chemistry 4R-0L-4C Prereq: CHEM 252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 561 Advanced Physical Chemistry 4R-0L-4C Prereq: CHEM 363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 562 Physical Polymer Chemistry 4R-0L-4C Prereq: CHEM 361 or CHE 303

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 570 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses. If cross-listed with CHEM470, students in CHEM570 will need to complete an additional project.

CHEM 595 Chemistry Seminar 0R-0L-0C F Prereq: None

Chemistry graduate students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 596 Chemistry Seminar 0R-0L-0C W Prereq: None

Chemistry graduate students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 597 Chemistry Seminar 0R-0L-0C S Prereq: None

Chemistry graduate students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.

CHEM CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Graduate Studies

Civil Engineering

Professors Aidoo, Chapman, Hanson, Kershaw, Lovell, Marincel Payne, McKinney, Mueller Price, Robinson, and Sutterer.

CE 101 Engineering Surveying 0R-6L2C F Prereq: None
Covers basic principles and practices of surveying. Measurement through the application of surveying techniques; theory of errors and their analysis; concepts of horizontal, vertical, and angular measurement; coordinate systems; basic surveying operations and computations; reading and interpretation of building, highway, and/or bridge plans; traverse computations; applications to construction and design.

CE 111 Geographical Information Systems 2R-0L-2C W Prereq: None
The course covers introductory concepts of geographical information systems and related technologies. Topics covered will relate to the use, collection, creation, and analysis of spatial data in applying GIS and related technologies to civil engineering projects.

CE 205 Thermodynamics 4R-0L-4C F Prereq: MA 112
Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

CE 250 Sustainable Civil Engineering Design 2R-0L-2C W Prereq: EM 103
An introduction to sustainable design of civil engineering systems. Includes treatment of current issues as they relate to design and construction for economic, environmental and social aspects of civil engineering.

CE 303 Engineering Economy 4R-0L-4C W Prereq: None
Emphasizes time value of money and factors related thereto. Familiarizes students with concepts of annual cost, present worth, and minimum rate of return as tools for consideration of economic factors pertinent to the selection of alternate solutions to engineering problems.

CE 310 Computer Applications in Civil Engineering 2R-0L-2C S Prereq: CE371 and CE432
Students develop solutions to a variety of civil engineering problems using application programs such as Mathcad, Excel, and Matlab. Emphasis is made on problem solving approach and structured programming with software tools useful to civil engineering computation and design.

CE 320 Civil Engineering Materials 3R-3L-4C S
A study of the origin, nature, performance and selection criteria of various basic materials used in the practice of civil engineering. These include aggregates, portland cement, concrete, and bituminous materials. Emphasis will be placed on standard methods of testing and characterization as related to the mechanical behavior of materials.

CE 321 Structural Mechanics I 4R-0L-4C F Prereq: EM 203
Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Prereq: EM 203 and EM 301
Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory

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- Army ROTC (Military)
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- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Prereq: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE380 Introduction to Transportation Engineering 4R-0L-4C S Coreq: MA223, CE320

Study of transportation functions and transportation systems; measuring and estimating demand; characteristics of transportation modes, interactions between modes, and mode interfaces; social, environmental, technological, economic, and public policy impacts; techniques of transportation system planning, design, and operation, with an emphasis on highway geometric design.

CE 400 Career Preparation Seminar 1R-0L-0C S Prereq: CE 488

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Prereq: CE 321

Hand methods for structural analysis of indeterminate structures: approximating drift of frames and solid walls, force method, moment distribution method, distribution of shear when there is a rigid diaphragm, and in-plane diaphragm forces.

CE 431 Structural Design in Steel I 3R-0L-3C S Prereq: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Prereq: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 436 Foundation Engineering 4R-0L-4C F Prereq: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Prereq: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C W Prereq: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 445 Construction Methods and Equipment 4R-0L-4C F Prereq: Senior class standing or consent of instructor

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Prereq: CE 321 and CE471

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will look at major environmental regulations and sustainability assessment tools. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Prereq: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air

quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Coreq: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 463 Unit Operations in Environmental Engineering 4R-0L-4C F Prereq: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 471 Water Resources Engineering 4R-0L-4C W Prereq: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Geometric Design of Highways and Streets 4R-0L-4C W Pre: CE101 & CE380

Highway planning and design with evaluation of multiple alignment alternatives; geometric design of highways: horizontal and vertical alignment, cross-sectional design; intersection design; earthwork measurements and quantities; reverse curve design; legal aspects of transportation engineering; proper use of the American Association of State Highway and Transportation Officials (AASHTO) design guidelines.

CE 481 Traffic Analysis and Design 4R-0L-4C F Pre: CE380

Study of fundamentals of traffic engineering; components of the traffic system; intersection types and design elements; basic variables of the traffic system (flow, capacity, level of service, delay); design and analysis of traffic signals and intersections; traffic control and traffic impact analysis; safety performance and traffic crash analysis; use of the Highway Capacity Manual and traffic analysis software.

CE 482 Urban Transportation Planning 4R-0L-4C F or W Pre: CE380

Applies general principles of planning, evaluation, selection, adoption, financing, and implementation of alternative urban transportation systems to urban and regional planning; formulation of community goals and objectives, inventory of existing conditions; transportation modeling-trip generation, distribution, modal choice, assignment, technological characteristics and operation of modern transit and other movement systems.

CE 483 Railroad Engineering 4R-0L-4C S Pre: Junior standing or consent of instructor

Provides an overview of rail transportation: history, organizations, economics, safety, freight operations, track-train dynamics, signals and communications, motive power and equipment, track components, construction and maintenance. The basic objective of the course is to gain an understanding of railroads as a transportation industry that merges a number of engineering fields as well as other disciplines that contribute to the success of a complex, growth- oriented industry.

CE 486 Civil Engineering Design & Synthesis I 1R-3L-2C F Prereq: RH 330, CE 460; Coreq: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be initiated by small teams of students to implement principles used in planning, design, and synthesis. Learning objectives include contracting, concept development, concept feasibility, planning and scheduling design work, data collection for subsequent design.

CE 487x Technical System Design & Synthesis 2R-2L-2C W Prereq: CE486; Coeq: CE 488

Technical system design of interdisciplinary elements of civil engineering projects submitted by corporate and governmental sponsors will be completed by individual team members to fulfill the needs of a team project initiated with CE486 and continuing in CE488. The "x" will be used to identify subdiscipline designation (c = general civil design, e= environmental, g = geotechnical, s = structural, t = transportation, w = water resources).

CE 488 Civil Engineering Design & Synthesis II 1R-2L- 2C W Prereq: CE486; Coreq: CE 487

Project management by small teams for civil engineering projects submitted by corporate and governmental sponsors will continue. Learning objectives include coordinate of major design work in subdisciplines, progress reporting to the client, critical path model management to keep the project on schedule to fulfill the needs of a team project initiated with CE486 and continuing in CE487.

CE 489 Civil Engineering Design & Synthesis III 1R-3L-2C S Prereq: CE 487, CE488

Civil engineering projects submitted by corporate and governmental sponsors will be completed. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. Learning objectives include construction planning and cost, final reporting, and public presentation of findings.

CE 490 Directed Studies 1-4C Arranged. F,W,S Prereq: Approval of department head, adviser, and

course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

CE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

CE 520 Structural Engineering Practicum 0R-12L-4C Prereq: Grad or consent of instructor

Structural engineering practicum approved by the department.

CE 521 Matrix Methods for Structural Analysis 4R-0L-4C F Prereq: CE 321

Derivation of the direct stiffness method for truss and frame elements. Derivation of the finite element method for 2D plate elements. Requires development of computer programs to implement the direct stiffness method.

CE 522 Structural Dynamics 4R-0L-4C W Pre: Grad or consent of instructor Co-Req: CE 521

Analysis and behavior of structural members and systems subject to dynamic loads including basic theory for single-degree-of-freedom and multi-degree-of-freedom analytical models of civil engineering structures; seismic hazard analysis and methods of analysis for seismic loads; response spectra; time history; and linear and nonlinear methods.

CE 523 Advanced Solid Mechanics 4R-0L-4C W Prereq: Grad or consent of instructor

The fundamentals of elasticity are introduced and related to various problems such as beams on elastic foundations, unsymmetrical bending, torsion of thin walled members, and curved beams. Introduction to the analysis and modeling techniques for existing and repaired structures. Design of retrofit measures for a variety of structures using advanced composite materials.

CE 524 Building Design 4R-0L-4C S Prereq: Grad or consent of instructor and CE421

Advanced structural analysis and design concepts for buildings: material nonlinearity, plastic design, pushover analysis, bracing, floor vibrations. Course culminates in a design project.

CE 525 Bridge Engineering 4R-0L-4C S Prereq: CE 421, CE 431, CE 432

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Introduces concepts of bridge engineering by providing the students with the necessary knowledge and skills to apply the AASHTO LRFD specifications for the analysis and design of highway and bridge superstructure components.

CE 530 Structural Design in Timber 4R-0L-4C On Demand Prereq: Senior class standing or consent of instructor

Presents the analysis and design of structures constructed of timber.

CE 532 Structural Design in Concrete II 3R-3L-4C F Prereq: CE 432

Advanced topics in reinforced concrete analysis and design such as serviceability, slender columns, two-way slabs, and strut-and-tie modeling.

CE 533 Connections and Detailing 4R-0L-4C S Prereq: CE 431 and CE 432

Analysis and design of structural systems with emphasis on detailing requirements; behavior of bolted and welded connections, including gusset plates, moment-resistant connections, and simple connections; design and analysis of base plate and anchoring systems; and an introduction to seismic detailing requirements.

CE 534 Structural Design in Masonry 4R-0L-4C On Demand Prereq: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C F Prereq: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Prereq: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 537 Retaining Structure Design 4R-0L-4C W Prereq: CE 336, CE 432

Covers the determination of earth pressures, selection of appropriate retaining wall types, and design of commonly used retaining structures. Includes both external (geotechnical) and internal (structural) analysis.

CE 561 Air Pollution 4R-0L-4C W Prereq: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Advanced Wastewater Treatment 4R-0L-4C Prereq: CE 463

Covers the theory, design and analysis of biological processes for the treatment of wastewater. Treatment processes include suspended and attached growth processes, aerobic and anaerobic processes, biological nutrient removal, aeration and gas transfer, and biosolids processing.

CE563 Advanced Water Treatment 4R-0L-4C Prereq: CE 463

Covers the theory, design and analysis of physical and chemical processes for the treatment of drinking water. Treatment processes include coagulation and flocculation, gravity separation, granular and membrane filtration, disinfection, air stripping, adsorption, ion exchange, and disinfection.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Prereq: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Prereq: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Prereq: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Prereq: CE 471

Watershed planning and stormwater management strategies are examined using computer simulation models. With an emphasis on conceptual foundation, students will be introduced to some of the most widely used models in the fields of hydrology and stormwater quantity management. Topics examined include watershed loss, transform, and routing methods, as well as model configuration, calibration, and evaluation.

CE 568 Surface Water Quality Modeling 4R-0L-4C S Prereq: CE 460 or consent of instructor

Covers the mathematical analysis of transport and fate of pollutants in natural surface waters and their impact on water quality using analytical and numerical models. Includes one- and two-dimensional steady-state and transient models. Pollutants examined include oxygen-demanding organics, nutrients and toxic compounds.

CE 569 Treatability Studies 2R-6L-4C On Demand Prereq: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 570 Modeling Open Channel Hydraulics 4R-0L-4C W Prereq: CE 371

Presents steady and unsteady flow problems in open channels and pipes, dealing with mechanics of flow over rigid and mobile boundaries. Covers analysis of river dynamics and hydraulic principles in stormwater conveyance through numerical and computer modeling.

CE 571 Environmental River Mechanics 3R-3L-4C S Prereq: CE 371

Concepts of fluvial geomorphology and fluvial hydraulics are examined, including natural stream flow, sediment transport, and ecological processes in alluvial rivers. Students will apply these principles to solve common design problems of channel instability and rehabilitation of impaired streams. Students will visit local streams to perform field data collection of channel geometry, bed and bank material, and water quality.

CE 573 Groundwater Analysis 4R-0L-4C Prereq: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and

unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Prereq: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Prereq: Consent of instructor
Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Prereq: Permission of instructor
A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering
Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S
Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science & Software Engineering

Professors Anderson, Bohner, Boutell, Chenoweth, Defoe, Fisher, Galluzzi, Hays, Hewner, Laxer, Mellor, Mohan, Mutchler, Rupakheti, Stamm, Stouder, Taylor, Wilkin, and Wollowski.

CSSE 120 Introduction to Software Development 3R-3L-4C F,W,S
An introduction to procedural and object-oriented programming with an emphasis on problem solving. Problems may include visualizing scientific or commercial data, interfacing with external hardware such as robots, or solving numeric problems from a variety of engineering disciplines. Procedural programming concepts covered include data types, variables, control structures, arrays, and data I/O. Object-oriented programming concepts covered include object creation and use, object interaction, and the design of simple classes. Software engineering concepts covered include testing, incremental development, understanding requirements, and teamwork.

CSSE 132 Introduction to Computer Systems 3R-3L-4C F,S Prereq: CSSE 120
Provides students with an understanding of system level issues and their impact on the design and use of computer systems. Examination of both hardware and software layers. Basic computation structures and digital logic. Representation of instructions, integers, floating point numbers and other data types. System requirements, such as resource management, security, communication and synchronization, and their hardware and/or software implementation. Exploration of multiprocessor and distributed systems. Course topics will be explored using a variety of hands-on assignments and projects.

CSSE 212 Hardware-oriented Programming 3R-3L-4C Prereq: ICS major
Simple computer architecture. Special hardware-oriented programming. Introduction to the C programming language, especially the use of pointers. Interrupt programming. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 220 Object-Oriented Software Development 3R-3L-4C F,W,S Prereq: CSSE 120
Object-oriented programming concepts, including the use of inheritance, interfaces, polymorphism, abstract data types, and encapsulation to enable software reuse and assist in software maintenance. Recursion, GUIs and event handling. Use of common object-based data structures, including stacks, queues, lists, trees, sets, maps, and hash tables. Space/time efficiency analysis. Testing. Introduction to UML.

CSSE 221 Fundamentals of Software Development Honors 3R-3L-4C F Prereq: A score of 4 or 5 on the APCS A exam or permission of instructor
This course is intended for students who have sufficient programming experience to warrant placement in an accelerated course covering the topics from CSSE 120 and CSSE 220. This course will satisfy the prerequisite requirements for courses that have CSSE 220 as a prerequisite.

CSSE 225 Programming 3 3R-3L-4C Prereq: ICS major
Differences between Java and C++. C++ concepts of object-oriented programming (classes, objects, inheritance, polymorphism). Storage management. Multiple inheritance, operator overloading, friend-concept, exception handling, I/O. Error analysis of programs. Generic programming and introduction to C++ - standard library. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 230 Data Structures and Algorithm Analysis 3R-3L-4C W,S Prereq: CSSE220 or CSSE 221 with a

- Air Force ROTC (Military)
- Army ROTC (Military)
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- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
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- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

grade of C or better, and MA 112

This course reinforces and extends students' understanding of current practices of producing object-oriented software. Students extend their use of a disciplined design process to include formal analysis of space/time efficiency and formal proofs of correctness. Students gain a deeper understanding of concepts from CSSE 220, including implementations of abstract data types by linear and non-linear data structures. This course introduces the use of randomized algorithms. Students design and implement software individually, in small groups, and in a challenging multi-week team project.

CSSE 232 Computer Architecture I 3R-3L-4C F, W Prereq: CSSE132, or CSSE120 and ECE233

Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic, ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control. Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prereq: CSSE220 or CSSE221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE 280 Introduction to Web Programming 3R-3L-4C W Prereq: CSSE220 or CSSE221

Introduction to the client-side and server-side mechanisms for creating dynamic web pages with persistent data storage. Browser-webserver interaction via HTTP. Static web page creation using HTML5 and CSS3. Client-side programming using JavaScript, DOM, JSON. Server-side programming and data storage using PHP and MySQL. Asynchronous client-server communication using AJAX and extensions of JavaScript. Session maintenance using cookies. Security considerations. This course provides breadth of knowledge of many tools/technologies rather than deep knowledge of any particular tool/language. No previous experience with web page creation is required.

CSSE 290 Special Topics in Computer Science 1 - 4C Arranged Prereq: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prereq: CSSE230

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W,S Prereq: CSSE220 or CSSE221, and CSSE132 or CSSE232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prereq: MA275 and CSSE230 (or concurrent enrollment in CSSE230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming

experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prereq: CSSE220 or CSSE221, and MA212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 352 Computer Game Development 4R-0L-4C Prereq: CSSE230

An introduction to designing and developing computer games. Topics include game genres, game design, sprites, game physics, collisions, characters, scripting, graphics, and sound. Students will design and implement their own game using an available game engine.

CSSE 371 Software Requirements Engineering 3R-3L-4C F Prereq: CSSE230, RH330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requ: CSSE371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict management. Professional issues including career planning, lifelong learning, software engineering ethics, and the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prereq: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Design 3R-3L-4C W Prereq: CSSE371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 3R-3L-4C S Prereq: CSSE374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prereq: CSSE230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 400 CSSE Seminar 4R-0L-4C Prereq: ICS major

This course presents an overview of current application areas within computer science and software engineering through the use of practical case studies. Students will undertake their own preparation of one or more case studies and present their results. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prereq: CSSE332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prereq: CSSE304

A survey of some current and emerging programming languages, focusing on unique language paradigms-ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing

independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prereq: CSSE232, CSSE304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prereq: CSSE230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prereq: CSSE220 or CSSE221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 435 Robotics Engineering 3R-3L-4C S Prereq: ME 430 or ECE 230

Interdisciplinary course in robotics focusing on communication, software development, kinematics, robot GUI design, sensing, control, and system integration. Labs in the course cover MATLAB GUI development with GUIDE, Denavit-Hartenberg parameters, Arduino programming, Arduino to Android communication, Android app development, and OpenCV4Android image recognition. Students in the course will program an Android + Arduino, 6-wheeled mobile robot with 5 DOF servo arm to participate in an outdoor GPS robotics challenge. Cross-listed with ME 435.

CSSE 433 Advanced Database Systems 4R-0L-4C S Prereq: CSSE333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prereq: CSSE332 and MA275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 443 Distributed Systems & IT Security 3R-3L-4C Prereq: ICS major

Building complex distributed information systems requires a systematic approach. This course covers the analysis of existing distributed information systems and provides the ability to model simple new distributed applications with special attention to the trustworthiness, reliability and security of information systems. Topics covered include the main architectural models of distributed systems, describing simple distributed applications according to architecture and function, defining simple communication protocols, the benefits of using middleware, the risks of using distributed systems, and safety measures. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 444 Real-time Systems 3R-3L-4C Prereq: ICS major

Students will learn the features and specifications of real-time systems. Topics covered include real-time operating systems and programming languages, design patterns for real-time systems, scheduling, synchronization, hybrid task sets, and applications of real-time systems. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prereq: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence R-0L-4C Arr Prereq: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prereq: CSSE220 or CSSE221, and MA212 (MA371 or MA373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prereq: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prereq: CSSE230 and MA375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 477 Software Architecture 4R-0L-4C F Prereq: CSSE374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 479 Cryptography 4R-0L-4C S Prereq: CSSE220 or CSSE221, and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 480 Web App Frameworks with AppEngine 3R-3L-4C F Prereq: CSSE230 and CSSE280

Development of desktop and mobile web applications using Google AppEngine. Additional web frameworks include Jinja2, Cloud Datastore, jQuery, Bootstrap, DataTables, Cloud Storage, Cloud Endpoints, and AngularJS. Topics covered using these frameworks include the HTML, CSS, and JavaScript development of client side web apps, sending and receiving REST requests, designing Datastore models, HTML5 and CSS3 features including CSS animations, file storage, Ajax requests, and user OAuth. Emphasis is on hands-on use of these frameworks in web application development. Includes a substantial team project (UI mockups, user stories, development, testing, and presentation).

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prereq: CSSE230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE 483 Android Application Development 4R-0L-4C Prereq: CSSE230

An introduction to programming mobile applications using the Android stack. Topics include the activity lifecycle, resources, layouts, intents for multiple activities, menus, fragments and dialogs, adapters, data persistence via

shared preferences, SQLite, and web backends. Emphasis is on hands-on use of these components in application development. Includes a substantial team project (UI mockups, user stories, UML design, development, testing, and presentation).

CSSE 484 iOS Application Development 3R-3L-4C W Prereq: CSSE230

An introduction to programming mobile applications using the iOS stack. Topics include using X-Code for Swift and Objective-C app development, UI components, Storyboards, view controller actions and outlets, table views, navigation controllers, Core Data, and APIs for backend communication. Emphasis is on hands-on use of these components in application development. Includes a substantial team project (UI mockups, user stories, development, testing, and presentation).

CSSE 487 Senior Research Project I 4C Arranged Prereq: RH330 and senior standing

CSSE 488 Senior Research Project II 4C Arranged Prereq: CSSE487

CSSE 489 Senior Research Project III 4C Arranged Prereq: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arranged Prereq: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arranged Prereq: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arranged Prereq: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arranged Prereq: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arranged Prerequisite: RH330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arranged Prerequisite: CSSE494

CSSE 496 Senior Thesis III 4C Arranged Prerequisite: CSSE495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Capstone Project I 4C F Prerequisite: CSSE371 and senior standing

CSSE 498 Senior Capstone Project II 4C W Prerequisite: CSSE 374 and CSSE497

CSSE 499 Senior Capstone Project III 4C S Prerequisite: CSSE498

For a capstone experience, students work on a team to complete a three-term software engineering project for an approved client. Students choose from two approaches to complete their capstone: 1) Develop a substantive software product, using defensible software processes. The teams focus on delivering key software development, administrative, and user artifacts to the client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure. 2) Investigate a substantive software product or engineering process problem, using a defensible and documented research approach. Tasks include problem analysis, developing alternative solutions, evaluating the solutions via prototyping and iterative processes of investigation, comparing the potential solutions, recording the investigation experience in a research report, and delivering the research artifacts to the client.

CSSE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Electrical & Computer Engineering

Professors Berry, Chang, Doering, Estrada, Grigg, Herniter, Hong, Hudson, Kim, Miller, Moore, Padgett, Rostamkolai, Simoni, Song, Throne, Walter, Wheeler, and Yoder.

ECE 160 Engineering Practice 0R-4L-2C F,W Prereq: none
An introduction to electrical and computer engineering, systems engineering design, programming, microcontrollers, soldering and circuit building. Students will work individually and on teams to complete projects and create a system for an end of term competition. Students will also learn about technical documentation and communication. Topics include functions, arrays, conditionals, loops, Boolean algebra, wireless communication, resistors, transistors, diodes motors, sensor, analog and digital inputs and outputs.

ECE180 Introduction to Signal Processing 3R-3L-4C F, W, S Pre: MA112 and either ECE160, or CSSE120 or prior programming experience
An introduction to discrete-time signal processing applied to audio, images, and video. Topics include phasor representation of sinusoidal signals, complex arithmetic, sampling, signal spectra, linear time-invariant systems, frequency response, convolution, filter implementation, and MATLAB programming. Integral laboratory.

ECE 203 DC Circuits 3R-3L-4C S,F Prereq: MA111 and PH112
A review of the definition of voltage, current, energy and power. An introduction to Ohm's Law, ideal DC independent and dependent voltage and current sources, resistors, inductors, capacitors, and operational amplifiers. Circuit analysis and simplification by using series, parallel, and Wye-Delta reduction, Kirchhoff's laws, mesh and nodal analysis, Thevenin, Norton and Maximum Power Theorems, superposition, and source transformations. An integral laboratory to build electric circuits and measure voltage, current, resistance and power.

ECE 204 AC Circuits 3R-3L-4C F,W Prereq: PH113 and either ECE203 with a grade of C or better or ES203 with a grade of C or better
Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Circuits and Systems 3R-3L-4C W, S Prereq: MA211, ECE180, RH131 and either ECE203 with a grade of C or better or ES203 with a grade of C or better
Introduction to 1st and 2nd order circuits and review of differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C W,S Prereq: MA 211
A course designed for engineers (other than electrical or computer) covering analysis of passive circuits, introduction to op-amps, instrumentation, sinusoidal steady-state, a-c power, and induction motors. EE and CPE majors may not take this course.

ECE 230 Introduction to Embedded Systems 3R-3L-4C W, S Pre: ECE233, CSSE 120 and ECE160

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

Sensors and actuators. Input and output devices. Microcontroller architecture. Standard communications protocols. Interrupt generation and processing. Data representation and storage. Memory management. The C programming language and programming styles. Integral laboratory and a term project.

ECE 233 Introduction to Digital Systems 3R-3L-4C F, W Pre: CSSE 120 or ECE160

Number systems, Binary arithmetic, logic gates, forming logic circuits. Boolean algebra, Karnaugh maps. Propagation delay, hazards, common Combinational logic circuits, structures, and design. Contraction, latches, flip-flops, finite state machines, counters, Sequential circuit timing, and designing Sequential circuits. Register design, control and datapath design. Basic computer architecture, including memory. Integral laboratory.

ECE 250 Electronic Device Modeling 3R-3L-4C S, F Pre: ECE204 or ECE205. For non-EE and non-Cpe majors: ES203 with B or better

Modeling, analysis, and simulation of electronic circuits that contain two-terminal and threeterminal semiconductor devices. Large-signal, biasing, and small-signal analysis models.

Introduction to wave shaping circuits, switching circuits, and amplifiers. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Prereq: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,S Prereq: ECE 380

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Integral laboratory.

ECE 312 Communication Networks 4R-0L-4C W Prereq: MA381, CSSE120

Layered architectures. Circuit and packet switching. The ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Queuing theory. Reliable message transport, internetworking.

ECE 320 Linear Control Systems 3R-3L-4C F,W Prereq: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C W,S Prereq: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C S Prereq: CSSE 232

Instruction-Level Parallelism. Pipelining. Data Hazards. Exceptions. Branch Prediction. Multilength Instructions. Loop Unrolling. TI C6000 Digital Signal Processor. Cache. Memory. MSP430 Microcontroller. PIC Microcontroller. Intel Itanium. Multiprocessors. Hardware Multithreading. Graphics Processors. Supercomputers.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Prereq: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Prereq: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 343 High-Speed Digital Design 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Signal path modeling through connecting lengths of transmission lines with lumped element models of discontinuities. Circuit parameters from geometries and material properties for resistance, capacitance, inductance and transmission line segments. Lossless and lossy transmission line circuit modeling. High-frequency and high-speed behavior of passive components. Frequency spectrum of digital signals. Digital device driver and receiver modeling. Transmission line impedance discontinuity and termination techniques. Electric and magnetic field coupling mechanisms for capacitive and inductive crosstalk. Ground noise, power plane noise and resonance. Signal and power integrity issues in high-speed digital systems at both the printed-circuit board and chip levels.

ECE 351 Analog Electronics 3R-3L-4C F,W Prereq: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal properties of op-amps. Integral laboratory.

ECE 362 Principles of Design 3R-0L-3C F,S Prereq: ECE204, ECE205, ECE230, ECE233, ECE250 and ECE300

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3R-1L-4C F,S Prereq: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, and wind technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C W,S Prereq: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C F,W Prereq: ECE 300 and MA381

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform. Random Variables and Random Processes.

ECE 398 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE 412 Software Defined Radio 3R-3L-4C S Prereq: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front end, and clock-jitter of the A/D. In the integral laboratory students will use LabVIEW to create a complete digital radio using the NI USRP 2920 platform.

ECE 414 Wireless Systems 4R-0L-4C W Prereq: ECE 310

Introduction to wireless communications and networks. Wireless channel models, vector space, modulation and demodulation, optimal receiver design, equalization, channel capacity, multipleaccess techniques, spread spectrum, and multiple-antenna systems. Additional recommended prerequisite: MA371 or MA373 with a grade of B or higher.

ECE 415 Wireless Electronics 2R-6L-4C Prereq: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with CHE 405, EP 410, and ME 416.

ECE 418 Fiber Optic Systems 4R-0L-4C S Prereq: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing systems, and optical networks. Topics include basic architectures, component overview, system design, and expected degradations along with mitigation techniques. An oral presentation of a technical paper is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Prereq: ECE 320 or ME 406

Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prereq: CSSE 120 and (ECE 320 or ME 406 or BE 350 or CHE 440)

This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Prereq: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Prereq: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Prereq: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, W Prereq: ECE362

For EE: Prereq or concurrent registration in the remainder of ECE230, ECE310, ECE320, ECE341, ECE351, ECE370 or ECE371, ECE380

For CPE: Prereq or concurrent registration in the remainder of CSSE332 or CSSE230, ECE250, ECE230, ECE312, ECE332, ECE343, ECE380 or ECE320

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W, S Prereq: ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W,S Prereq: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Prereq: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Prereq: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Prereq: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Prereq: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/OE 437 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Prereq: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Prereq: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Prereq: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Prereq: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Prereq: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor

Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ME 519, EP 511, and CHE 519.

ECE530 Advanced Microcomputers 3R-3L-4C S Prereq: Graduate standing and ECE 331 or ECE 230; or ECE 331 or ECE 230 with a grade of B or better; or consent of instructor

32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software debugging tools. Integral laboratory.

ECE 531 Digital Test and Product Engineering 3R-3L-4C S Pre: Graduate standing and ECE230 Intro to Embedded Systems, ECE233 Intro to Digital Systems and ECE250 Electronic Device Modeling; or ECE230, ECE233, and ECE250 with grades of B or better in all three courses; or consent of instructor.

Industrial testing techniques for microcontrollers and other digital integrated circuits. Includes common digital system fault modeling, test generation, and design for testability in addition to memory testing strategies. Integral labs using an industrial grade automatic test environment (ATE).

ECE534 Advanced Signal and Power Integrity 4R-0L-4C W Prereq: Graduate Standing and ECE341, ECE342, or ECE343; or ECE341, ECE342, or ECE343 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal and power integrity modeling and measurement in high-speed digital systems at IC, PCB, and chassis levels. High-frequency behavior of passive components and packages. Behavior and SPICE models of drivers and receivers. Lossy transmission lines and discontinuity characterization. Mixedmode s-parameters and other network parameters. Frequency and time-domain modeling of capacitive and inductive crosstalk. Differential signaling techniques; timing conventions. Synchronization. Signal equalization. Power plane noise and resonance. High-speed PCB design guidelines. Measurement techniques including time-domain reflectometry, vector network analyzer and impedance analyzer. PCB simulation. Full-wave simulations.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Prereq: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of instructor

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C W Prereq: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Wave-guiding structures, microwave network analysis, scattering parameters, Z, Y and ABCD parameters, passive devices and components, design, fabrication, simulation and measurement of microwave devices and components, matching strategies, multi-conductor transmission lines and crosstalk.

ECE542 Advanced Electromagnetics 4R-0L-4C F Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, EM field theorems, potential functions, power and energy, material properties, wave propagation, reflection and transmission, radiation, scattering, Green's functions, metamaterials and metamaterial-inspired structures, modeling & simulation, measurement technique.

ECE543 Electromagnetic Metamaterials 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Electromagnetic fundamentals, control of permittivity and permeability, dispersion, causality, double-negative materials, epsilon near-zero materials, transmission line-based metamaterials, composite right/left handed wave-guiding structures, even/odd mode analysis, differential signaling, electromagnetic bandgap structures, phase control, dual band devices, enhanced bandwidth devices, zeroth-order resonators, full wave simulation, device fabrication and laboratory measurement.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Prereq: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Prereq: Graduate standing and ECE351 and ECE380, or ECE351 and ECE380 with a grade of B or better in both courses, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C S Prereq: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C S Prereq: Graduate standing and ECE351, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Analog signal processing techniques using operational amplifiers. A/D and D/A converters. Protection from electric shock. Measurement of biological potential waveforms (ECG, EMG, EEG, ENG, EOG, ERG). Ultrasound techniques and instrumentation. X-ray CAT techniques. No laboratory, but many in-class demonstrations and emphasis on circuit simulation.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C S Prereq: Graduate standing and ECE 351; or ECE 351 with a grade of B or better; or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE 557 Analog Test and Product Engineering 3R-3L-4C F Prereq: Graduate standing and ECE 300 and ECE 351; or ECE 300 and ECE351 with grades of B or better in both courses; or consent of instructor

Fundamental skills necessary to be an industrial integrated circuit test engineer or product engineer. Includes the economics associated with testing, impact of fabrication variation on devices, instrumentation associated with industrial testing, turning a data sheet into a test plan, industrial testing techniques for analog circuits, trade-offs between test time and test accuracy, statistical analysis of the data and statistical process control, the use of device interface boards necessary to control device loading for different tests. Integral labs with an industrial grade automatic tester (ATE).

ECE 558 Mixed-Signal Test and Product Engineering 3R-3L-4C W Pre: Graduate standing and ECE300 Continuous Time Signals and Systems, ECE233 Intro to Digital Systems, and ECE351 Analog Electronics; or ECE300, ECE233, and ECE351 with grades of B or better in all three courses; or consent of instructor.

Industrial testing techniques for AC and DC tests of mixed-signal integrated circuits using an automatic test environment (ATE). Includes the structure and operation of comparators and standard data converters (DACs, ADCs), common data converter datasheet specifications, impact of data converter design on testing strategies, and statistical analysis of accuracy-time trade-offs. Integral labs using an industrial grade ATE.

ECE580 Digital Signal Processing 4R-0L-4C W Prereq: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Prereq: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 120 or ME 123 and SR standing or GR standing.

Introduction to image segmentation and recognition. Use of neural networks, fuzzy logic and morphological methods for feature extraction. Advanced segmentation, detection, recognition and interpretation. Relevant

laboratory experiments and required project. Cross-listed with OE 537.

ECE 583 Pattern Recognition 3R-3L-4C S Prereq: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 584 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and ECE300, or ECE300 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as BE541.

ECE 597 Special Topics in Electrical Engineering 4C Prereq: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C Arranged

Thesis topic selected in consultation with adviser. Graduate students only.



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Engineering Management

Professors Andrijcic, Downing, Hamasha, James, Kline, Schumacher and Stamper

EMGT ESC - Escalate Program Participant - 0C

Students participating in the Escalate entrepreneurship program will be enrolled in this zero credit section each quarter. The course will be graded S or U. A grade of S will be given for completing the required Escalate courses, attending required professional development activities, and completing required project activities. Only students in the Escalate cohort may enroll in this section.

EMGT100 Introduction to Entrepreneurship 4R-0L-4C

This course provides an overview of the principles of entrepreneurship and becoming an entrepreneur in today's society. Topics include opportunity identification, market investigation, product development, developing marketing and business plans, and understanding business, financial, and legal matters related to venture creation. Concepts from the lean startup and canvas tools will be applied.

EMGT152 Economic Thinking for Entrepreneurs 1R-0L-1C Corequ: SV151 or consent of instructor

During this course students discuss the economic implications of entrepreneurial actions.

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4CPre: Junior, Senior, or consent of instructor

Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC Pre: MG 461 or consent of instructor

Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC Pre: MG 462 or consent of instructor

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT511 Graduate Seminar I 1R-0L-1C F

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT512 Graduate Seminar II 1R-0L-1C W

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT513 Graduate Seminar III 1R-0L-1C S

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT514 Graduate Seminar IV 1R-0L-1C Summer

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT520 Accounting for Technical Managers 4R-0L-4C Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership & Organizational Culture 4R-0L-4C Management

This course reviews the management literatures on leadership and organizational culture. It explores that interaction and the range of differences found in practice. Additional topics include: Organizational Change, Vision & Strategy, Business Ethics, and Senge's Learning Organization. Course activities include the 'Winning At Design Automation' simulation that demonstrates cultural issues surrounding rapid growth in a high tech, high commitment company, and The Ethics Challenge game. Students select a company as the topic of their term paper, describing its culture (Schein's approach) and a plan to promote change (Conger's Charismatic Leadership). Students make a 'call to action' speech to convey their leadership plan.

EMGT523 Marketing in New Product Development 4R-0L-4C Management

This course explores marketing concepts and marketing strategy within the context of new product development.

Topics addressed include: market research methods, market segmentation, product positioning (4 Ps), pricing strategies, alliances, elasticity, advertising & brands, and the champion role. Student projects define a new product idea, apply course concepts to the development of that idea (segmentation, pricing, etc.) and present their analysis to the class. The course includes the 'NPDCChallenge'simulation that demonstrates marketing issues an entrepreneur faces in developing a new product.

EMGT524 Production/Operations Management 4R-0L-4C Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-0L-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-0L-4C

This course introduces the concepts of innovation types (radical, incremental, disruptive, open), invention, and diffusion to identify patterns of technology change. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, Delphi, roadmapping, and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-0L-4C Technical or Management

This course presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, estimating, scheduling, Mythical Man Month, Critical Path & Critical Chain, task partitioning & communication, rework, and negotiation. Students apply these concepts in writing case analyses. Typical problems and success factors are discussed in relation to project management choices. Special issues encountered in virtual teams are discussed.

EMGT529 Organizational Behavior 4R-0L-4C

This course will introduce students to principles and theories related to management and organizational behavior. The goal is to transfer or develop knowledge and skills for high performance in a complex technical business environment requiring engineers to make and communicate sound decisions, and react appropriately to unanticipated events. The concepts and techniques for maximizing the effectiveness of engineers in the achievement of organizational and project goals are also emphasized. Topics include power, teaming, motivation, selection, and development while understanding individual characteristics, attitudes, and behaviors. Additionally, we will examine how the use of Emotional Intelligence (EI) will be useful to the advancement of organizations that are culturally diverse.

EMGT531 Economics for Technical Managers 4R-0L-4C Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C Management

This course presents the Constructivist theory of communication and its application. The culture concept is applied at ethnic (~70%) organizational and interpersonal levels. The course balances theory and application and students write analysis of videos to apply course concepts. Students use Spradley's Ethnoscience approach to conduct interviews and write an ethnography for their term paper. The course helps students to better: develop interpersonal relations, improve their interviewing skills, analyze cultures, and understand diversity across ethnic & gender differences. Concepts include: Culture Shock, Empathy, The Social Construction of Reality, Non Verbal Communication, High & Low Context cultures, M time & P time cultures.

**EMGT534 Management Science 4R-0L-4C F (even years) Prereq: Senior or graduate standing
Technical or Management**

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-0L-4C Management

This course samples the strategy literature and distinguishes economic and managerial (resource based view) perspectives. Strategy issues encountered in transnational management are addressed in cases. Scenario planning is described. Trends and implications of globalization are explored (off shoring, 'rise of the rest', resource use & climate change, BOP, Business Model change) and the 'great recession' is discussed from a long wave perspective. Strategy implementation issues are addressed. Students develop strategies for an organization of their choice and evaluate those strategies using the 'Scenario to Strategies' approach in their term paper.

EMGT536 Leadership and Global Challenges 4R-0L-4C

This course examines the art of leadership and its development in our increasingly globalized society. In this course students will apply their general education and use their knowledge, experience, and perspectives learned in a variety of disciplines to investigate the nature and dynamics of leadership. Examining general theoretical approaches, with close attention to the unique challenges which globalization and cross-cultural interactions impose upon leaders, the class will work on three case studies. The first case study focuses on an individual in order to illustrate leadership development. The second will focus on a corporation in order to illustrate mutual influence of leaders, constituents, and organizations. The third will be about an event or a situation which exemplifies the challenges and creativity of leadership in global/transnational/multicultural operations.

EMGT537 Facilities Management 4R-0L-4C Prereq: SR or GR Class standing or consent of instructor

This course provides comprehensive analysis of the major issues in facilities management and planning of production and service facilities. The course emphasizes the use of quantitative and qualitative analysis in the design process. Topics include facility location, plant layout, space requirements, materials handling, personal requirements, system flow analysis, facility design, design algorithms, and distribution systems.

EMGT538 Product Realization 4R-0L-4C Prereq: SR or GR Class standing or consent of instructor

This course focuses on new product realization process. It provides fundamental methods and complimentary strategies for product realization. The major focus is on product development teams, idea and concept generation, concept evaluation and selection, customer needs, product function and architecture, design for manufacture and assembly, design for environment and safety, prototyping, product development, product evaluation for cost and performance, and product launch and support.

EMGT540 Fundamentals of Engineering Management 4R-0L-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT 551 Intellectual Property for Engineers and Scientists 4R-0L-4C Technical or Management Elective

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-0L-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of

engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT562 Risk Analysis and Management 4R-0L-4C

This course will introduce students to principles and methods of risk analysis and risk management, as related to diverse engineering and socio-technical systems. Students will learn how to: identify, prioritize and quantify risks; perform qualitative and quantitative risk assessments and develop risk models; assess uncertainty; identify, evaluate, and prioritize risk management alternatives; and communicate risk to stakeholders. Through the use of varied example problems and case studies, students will develop an understanding of the appropriate use of risk analysis and management methods for engineering and policy decision making under uncertainty.

EMGT564 Systems Architecture 4R-0L-4C Prereq: Senior standing or consent of instructor

This class will introduce students to the art and science of systems architecting, where systems architecting refers to uncovering the fundamental structure of a system (functional, physical, logical, operational) defined in terms of system's elements, interfaces, processes, constraints, and behaviors that must operate under specific requirements and constraints. Focus will be placed on investigating the broader meaning of architectures, as they relate to organizations and businesses, in addition to engineered systems and products. Students will be introduced to heuristic and model-based approaches for systems architecting. Through case-studies and example problems in areas of production and manufacturing systems, intelligent transportation systems, social systems, and others, students will be able to apply the principles, processes and tools of systems architecting in order to structure and support the system development process of a balanced, well-integrated and socially and financially acceptable system.

EMGT567 Economic Analysis of Engineering Projects 4R-0L-4C Prereq: Senior standing or consent of instructor

This class will introduce students to critical principles of economic analysis of engineering projects. In particular, students will explore the process of making economic decisions under the influence of possibly uncertain future conditions and events. These economic decisions might involve investing in new facilities, improving existing production processes, or developing and marketing new products or services in the private and public sectors. Deterministic and multi-attribute evaluation approaches will be discussed. Students will be introduced to methodologies including capital budgeting, cost estimating, various alternative comparison methods, and life cycle costing. Additionally, students will be introduced to the concept of welfare economics through which they will explore economic impacts of infrastructure projects in the public sector. Emphasis will be placed on systems thinking and a systems approach to defining and solving economic problems.

EMGT570 Lean Six Sigma 4R-0L-4C Prereq: SR or GR Class standing or consent of instructor

This course focuses on the current lean six sigma engineering and technology techniques, principles, and philosophies relevant to manufacturing and service sectors. The course content emphasizes the DMAIC (Define, Measure, Analyze, Improve and Control) methodology in combined with the Lean techniques and practices through analytical and quantitative tools. Students will practice lean six sigma tools and methods by applying the DMAIC framework on practical problems in order to improve processes, increase efficiency, reduce or eliminate wastes and variation, and/or save money.

EMGT571 Operations Research for Technical Managers 4R-0L-4C Prereq: SR or GR Class standing or consent of instructor

This is a general operations research course structured for technical managers. It covers the application of scientific methods to business management, providing a quantitative basis for complex decisions. The focus is on complementary concepts and methods of decision and risk Analysis, inventory models, stochastic models, queuing systems, simulation modeling, and solving practical operations research problems using linear, non-linear, and integer models.

EMGT572 Reliability Engineering 4R-0L-4C Prereq: SR or GR Class standing or consent of instructor

This course provides fundamental concepts and complimentary methods and techniques in Reliability Engineering. It also provides various practical applications in Reliability Engineering. The major focus is on fundamental concepts, basic and advanced reliability models, systems reliability analysis, maintainability and availability, design for reliability and maintainability, practical reliability testing, analysis of failure data, failure and repair distribution, and practical case studies.

EMGT581 Multi-objective Optimization 4R-0L-4C Prereq: Senior standing or consent of instructor

This course will consider how humans make optimal decisions in an uncertain environment, when they have to simultaneously satisfy multiple objectives/goals under limited resources. Specifically we will consider: how to structure multi-objective problems, different methods and theories of quantifying preferences over multiple objectives a priori or a posteriori, multi-objective optimization methods without preference specification, multi-

attribute utility theory, value trade-offs, risk attitudes, and other topics like fuzzy methods. We will also consider the applications of these theories and methods to various problems, including managerial and operational business issues, public policy issues, development of new businesses, etc.

EMGT584 Systems Thinking and Evaluation 4R-0L-4C

This course will focus on applying systems thinking and methodologies, as well as parametric and nonparametric statistical methods to evaluate alternative system designs and design performance measures. Students will learn how to: identify and evaluate system goals, requirements and performance measures; design experiments to assess system performance; apply decision analysis techniques to diverse trade studies; and generate a business case for presenting technical analysis results.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization. Cross-listed with EMGT 486.

EMGT587 Systems Engineering 4R-0L-4C Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Prereq: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific

prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Industry Partners
Trustees
Parents

Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Engineering Mechanics

EM 301 Fluid Mechanics 4R-0L-4C S Prereq: EM 202

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

EM403 Advanced Mechanics of Materials 4R-0L-4C S Prereq: EM 203 or EM 204

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

EM 406 Vibration Analysis 4R-0L-4C F Prereq: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

UNDERGRADUATE-GRADUATE COURSES

EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Prereq: ME401 or consent of instructor

Course may be repeated for different topics in fluid mechanics.

EM 502 Advanced Dynamics 4R-0L-4C Prereq: ES 205

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

EM 503 Advanced Vibration Analysis 4R-0L-4C W Prereq: EM 406

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.

EM 505 Theory of Elasticity 4R-0L-4C Prereq: EM 203 or EM 204

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Prereq: EM 403 and MA 330

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher,Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 180 Engineering at Nanoscale 2R-0L-2C S
Introduction to nanoscience and engineering: properties and behavior of materials, devices, and systems (natural and artificial) at nanoscale, applications of nanoscience. Characterization techniques: Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), and thin film measurements. Basic cleanroom safety and experience, microfabrication processing techniques: photolithography, thin film deposition. Intro to design and data analysis software.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W
Scaling laws in small systems; electronics and photonics devices and systems, basics of quantum and statistical mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, Nanophotonics in metals and semiconductors, surface plasmon resonance and applications, photonic bandgap crystals.

EP 290 Directed Study Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 330 Material Failure 3R-3L-4C W Prereq: PH112
Principles of material failure; appearance, physical cause and mathematical description with emphasis on the materials used for micro-scale devices and assemblies. Failure types considered include Rupture, Fatigue, Creep, Corrosion, Electromigration, Electrical Overstress, Electrical Discharge and Thermal. Experiments illustrate the failure type and the machines used to study them. These include Electron, Optical and X-ray microscopes, Spectroscopy and Tension machines. A brief description of the working of each machine will be given.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S
Scaling laws in small systems; mechanical, biological, fluidics, and thermal systems. Nanomaterials and nanofabrication. Nanomechanics: cantilever oscillation, atomic-force microscopy (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors. Nanoscale optics, Nanoscale heat: conduction, convection, and blackbody radiation. Basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise. Cross-listed with EP 506.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

EP 407 Semiconductor Fabrication & Characterization 2R-6L-4C F Prereq: PH405 or JR/SR standing & consent of instructor

Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation.

EP 408 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410 or equivalent course

Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-listed with ECE 419, and CHE 419.

EP 415 Engineering Physics Design I 2R-6L-4C S Prereq: OE 280 or EP 280 & JR/SR standing Coreq: RH 330

Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with OE 415.

EP 416 Engineering Physics Design II 2R-6L-4C F Prereq: EP 415

Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with OE 416.

EP 417 Engineering Physics Design III 2R-6L-4C W Prereq: EP 416

Continuation of EP 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with OE 417.

EP 450 Nanomedicine 4R-0L-4C Prereq: PH113 or JR/SR standing & Consent of instructor

Material presented includes the functions and properties of medical nanodevices, the design and fabrication of nanorobots and nanoparticles, the current and potential applications of nanomedicine. Introduction to cancer cell biology and techniques for selective targeting of cancer cells, simulations of the optical and thermal properties of normal and cancerous cell organelles. Nanoplasmonics: Lorentz-Mie simulations of optical properties of nanoparticles, the use of plasmonic nanoparticles in diagnosis and therapy. Introduction to the nanophotodynamic therapies and the new dynamic modes in selective nanophotothermolysis of cancer, the design and methods of activation of nanodrugs. Time and space evolutions of thermal fields in and around the nano- bio-particles and nanoclusters. Ablation of the soft and hard biological tissues by activated nanoparticles.

EP 470 Special Topics in Engineering Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member.

May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 406.

EP 507 Semiconductor Fabrication and Characterization 2R-6L-4C F Prereq: PH405 or consent of instructor

Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both EP 407 and EP 507.

EP 508 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410/510 or consent of instructor


Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Science

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 211 Differential Equations (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 212 Matrix Algebra & Systems of Differential Equations (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,

- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,
- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Prereq: EM 121, MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better

Extend the conservation and accounting framework to examine fluid motion. Topics include dimensional analysis, pressure variation in both stationary and moving fluids, viscous effects including boundary layers, laminar and turbulent flow. Applications include lift and drag, pipe flow, compressible flow. Fundamental concepts are enriched by laboratory experiences.

ES 203 Electrical Systems 3R-3L-4C F,W,S Prereq: MA 113, PH 112, and EM 121 (or EM 120)

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better; ME 123 or BE 100 or CSSE 120 (or equivalent). Coreq: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Prereq: ES 203 with a grade of C or better, or ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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<p>GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Prereq: CHEM 111</p> <p>Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.</p>	
	Air Force ROTC (Military)
	Army ROTC (Military)
	Biology & Biomedical Engineering
	Biomathematics
	Chemical Engineering
	Chemistry and Biochemistry
	Civil Engineering
	College & Life Skills
	Computer Science & Software Engineering
	Electrical & Computer Engineering
	Engineering Management
	Engineering Mechanics
	Engineering Physics
	Engineering Science
	Geology
	Humanities and Social Sciences
	Mathematics
	Mechanical Engineering
	Multi-Disciplinary Studies
	Optical Engineering
	Physics

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Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Mathematics

Professors All, Broughton, Bryan, Butske, Carlisle, Eichholz, Finn, Goulet, Graves, Green, Grimaldi, Heyman, Holden, A. Holder, L. Holder, Isaia, Langley, Leader, McSweeney, Rader, Reyes, Rickert, Selby, Shibberu, Tabing and Tarrant.

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Prereq: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.
A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen. Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

MA 111 Calculus I 5R-0L-5C F,W
Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

MA 112 Calculus II 5R-0L-5C F,W,S Prereq: MA111
Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

MA 113 Calculus III 5R-0L-5C F,W,S Prereq: MA112
Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

MA 190 Contemporary Mathematical Problems 2R-0L-2C S Co-requisite: MA113
A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and applications, famous problems, and outstanding problems of great significance.

MA 200 Career Preparation 1R-0L-1C W
This course is for mathematics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200 and PH200.

MA 211 Differential Equations 4R-0L-4C F,W, S Prereq: MA113
First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F,W,S Prereq: MA113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F,W,S Prereq: MA112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to probability concepts, and random variables. A Central Limit Theorem will be presented. Inference (hypothesis testing and confidence intervals) for one mean, two independent means, and two means from a paired sample will be covered. An introduction to one factor analysis of variance and simple linear regression will be presented. Time permitting, inference for a one proportion and one standard deviation/variance are discussed. Both classical methods for inference as well as modern resampling methods are presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Prereq: MA112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Prereq: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W (odd years) Prereq: MA113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F,S Prereq: MA113, MA212

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F, W Prereq: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C F,S Prereq: MA211 and MA212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Prereq: MA211, MA212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA 342 Computational Modeling 4R-0L-4C S Prereq: MA212 and one of CHE310, CE310 ,MA332 or ME323

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 351-6 Problem Solving Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Prereq: MA275 and MA113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Prereq: MA212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Prereq: MA212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Prereq: MA212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Prereq: MA275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Prereq: MA275

An introduction to Group Theory. Topics include: matrix groups, groups of integers modulo a natural number, symmetric and dihedral groups, homomorphisms, subgroups, cosets, quotient groups and group actions. Applications, possibly including games and puzzles, cryptography, and coding theory. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Prereq: Consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F,W,S Prereq: MA113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including

these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C F Prereq: MA381

This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the Central Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Prereq: MA223 or MA382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 384 Data Mining 4R-0L-4C Prereq: CSSE120, MA 212 and either MA223 or MA381

An introduction to data mining for large data sets, include data preparation, exploration, aggregation/reduction, and visualization. Elementary methods for classification, association, and cluster analysis are covered. Significant attention will be given to presenting and reporting data mining results. Same as CSSE 384.

MA 385 Quality Methods 4R-0L-4C S Prereq: MA223 or MA382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 385

MA 386 Statistical Programming 4R-0L-4C Prereq: previous programming course and either MA223 or MA382

Computational data analysis is an essential part of modern statistics. This course provides a practical foundation for students to compute with data. This course will introduce students to tools for data management, manipulation and analysis that are common in statistics and data science. The R computing language will be introduced. Topics will include data structures in R, writing functions, webscraping, data cleaning (both quantitative and textual data), processing unstructured data, static and interactive graphical presentations of data, and coding of modern algorithms for data analysis (bootstrapping and Monte Carlo methods).

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Prereq: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 390 Topics in the Mathematics of Engineering 1-2C Arranged Prereq: consent of instructor

A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

MA 421 Tensor Calculus and Riemannian Geometry 4R-0L-4C Arranged Prereq: MA330

An introduction to the calculus of tensor fields and the local geometry of manifolds. Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

MA 423 Topics in Geometry 4R-0L-4C Arranged Prereq: MA371 or MA373 or consent of instructor

An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C Arranged Prereq: Instructor permission

A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C Arranged Prereq: MA330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to “direct methods.” Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Prereq: MA212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C Arranged Prereq: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 435 Finite Difference Methods 4R-0L-4C W Prereq: MA332 or MA371 or MA373 or MA433

An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Prereq: MA330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green’s function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Prereq: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Prereq: MA212 and one of MA371 or MA373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development “from the ground up.”

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Prereq: MA223 or MA381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Prereq: MA375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this

course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C Arranged Prereq: Instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C Arranged Prereq: MA366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C Arranged Prereq: MA366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C Arranged Prereq: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Prereq: MA371 or MA373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Prereq: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C Arranged Prereq: MA375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Prereq: MA375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Prereq: MA375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C Arranged Prereq: MA 378 or MA375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Prereq: CSSE220 and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key

cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C Arranged Prereq: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Prereq: MA382, or MA381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Prereq: MA223 or MA382

This course introduces statistical techniques for addressing the challenges that arise in the analysis of data from the biological sciences (including biology, biomedical engineering, and the medical community). Topics include linear regression modeling, nonlinear regression, repeated measures analysis (including mixed models), and survival/reliability analysis (analysis of time-to-event data). Flexible modeling strategies including relaxing linearity and distributional assumptions are discussed. Additional topics are introduced when discussing articles found in the literature, including properties of study design, power, meta-analysis, missing data, and causal inference. No prerequisite knowledge of biology is assumed. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Prereq: MA212 and either MA223 or MA382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Prereq: MA223 or MA382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics Variable credit Prereq: Consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Prereq: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Prereq: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F,W Prereq: MA492 or permission of the instructor

MA 494 Senior Project III 2C W,S Prereq: MA493

Either participation in a sponsored project or investigation of a problem with a substantial mathematical application, modeling and/or computational content. Students either work individually or in a team typically of 2 or 3, under the supervision of the faculty adviser (course instructor), interacting with the sponsor (if there is one). Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of the

Senior Project must be completed in a form acceptable to the adviser and the sponsor if there is one. A submitted written report and public presentation to department are required

MA 495 Research Project in Mathematics Variable credit Prereq: Consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate

guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Prereq: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Prereq: MA496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Prereq: MA497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

MA CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Prereq: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C Arranged Pre: MA381


Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C Arranged Prereq: MA223 or MA381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Prereq: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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Mechanical Engineering

<p>Professors Adams, Bernal, Bercich, Brackin, Burchett, Cantwell, Chambers, Cornwell, Cunningham, Fisher, Jones, Kawano, Layton, Lui, McCormack, Mayhew, Mech, Mirth, Moorhead, Moseley, Olson, Onyancha, Purdy, Richards, Riley, Sanders, Stamper, White and Winck.</p> <p>ME 123 Computer Programming 4R-0L-4C F,W,S Prereq: ME/PHOE major or permission of instructor Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion, presentation software, and spreadsheets. Introduction to teaming and creativity.</p> <p>ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S Selected student design projects. May include testing and/or computer aided design.</p> <p>ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Sophomore class standing Selected student design projects. May include testing and/or computer aided design.</p> <p>ME 301 Applications of Thermodynamics 4R-0L-4C F,W Prereq: ES 201 with a grade of C or better or CE205 Extend the conservation and accounting framework to examine energy-conversion systems. Topics include thermodynamic properties of pure substances, gas mixtures, exergy analyses, power and refrigeration cycles, psychrometric processes, combustion, and propulsion.</p> <p>ME 302 Heat Transfer 4R-0L-4C S,F Prereq: MA 211 and ES 202 or CHE 301 or EM 301 Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.</p> <p>ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Prereq: ES 202 Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.</p> <p>ME 317 Design for Manufacturing 3R-0L-4C W Prereq: EM 104 This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.</p> <p>ME 318 Material Processing in Manufacturing 4R-0L-4C Prereq: ME 328 An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering manufacturability when making material selection decisions in design.</p> <p>ME 321 Measurement Systems 3R-3L-4C W,S Prereq: EM 103, ES 205, MA 223</p>	<div><div>Air Force ROTC (Military)</div><div>Army ROTC (Military)</div><div>Biology & Biomedical Engineering</div><div>Biomathematics</div><div>Chemical Engineering</div><div>Chemistry and Biochemistry</div><div>Civil Engineering</div><div>College & Life Skills</div><div>Computer Science & Software Engineering</div><div>Electrical & Computer Engineering</div><div>Engineering Management</div><div>Engineering Mechanics</div><div>Engineering Physics</div><div>Engineering Science</div><div>Geology</div><div>Humanities and Social Sciences</div><div>Mathematics</div><div>Mechanical Engineering</div><div>Multi-Disciplinary Studies</div><div>Optical Engineering</div><div>Physics</div></div>
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Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Numerical Methods in Engineering 1R-3L-2C W,S Prereq: ME 123, or CSSE 120, MA 212

Engineering problems often lead to analytically intractable equations. This course combines structured programming and applied numerical methods to obtain approximate engineering solutions. Strategies include root finding, numerical integration, finite difference, initial value and boundary value problems. Matlab is used as the programming language for solving iterative problems numerically.

ME 328 Materials Engineering 4R-0L-4C W Prereq: CHEM 111

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Prereq: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 397 Special Topics in Mechanical Engineering 4R-0L-4C

Topics of current interest in mechanical engineering at the 300-level.

ME 401 Foundations of Fluid Mechanics 3R-3L-4C Prereq: ES 202 or EM 301, MA 212

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

ME 402 Advanced Heat Transfer 4R-0L-4C Prereq: ME 302

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

ME 403 Kinematics of Machinery 4R-0L-4C Prereq: ES 204 and (ME323 or CSSE220 or ECE230 or MA332)

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

ME 405 Theoretical Aerodynamics 4R-0L-4C W Prereq: ES 202

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

ME 406 Control Systems 3R-3L-4C F Prereq: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Prereq: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are taken when available.

ME 408 Renewable Energy 4R-0L-4C Prereq: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C S Prereq: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Prereq: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Prereq: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Prereq: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 410, ECE 416, and CHE 405.

ME 417 Advanced Materials Engineering 4R-0L-4C Prereq: ME 328 and EM 203 or EM 204

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ECE 466, CHE 420, and CE 420.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Prereq: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Prereq: EM204

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Prereq: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Prereq: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of

forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Prereq: ES 205 or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

ME 430 Mechatronic Systems 3R-3L-4C F,W Prereq: ME 323 or CSSE 220 or ECE 230

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

ME 435 Robotics Engineering 3R-3L-4C S Prereq: ME 430 or ECE 230

Interdisciplinary course in robotics focusing on communication, software development, kinematics, robot GUI design, sensing, control, and system integration. Labs in the course cover MATLAB GUI development with GUIDE, Denavit-Hartenberg parameters, Arduino programming, Arduino to Android communication, Android app development, and OpenCV4Android image recognition. Students in the course will program an Android + Arduino, 6-wheeled mobile robot with 5 DOF servo arm to participate in an outdoor GPS robotics challenge. Cross-listed with CSSE 435.

ME 447 Visualizing Data 4R 0L 4C. Prereq: Junior standing.

The course is about creating truthful and compelling data visuals. We study elements of statistical analysis, programming in R, human perception, graphic design, and visual rhetoric and ethics. After successfully completing this course, students should be able to design effective and truthful data displays, credibly explain their design rationale, produce publication quality visuals, and credibly critique a data display. Prior experience with R is not required.

ME 450 Combustion 4R-0L-4C Prereq: ME 301

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises.

ME 461 Aircraft Design 4R-0L-4C F Prereq: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams.

ME 462 Thermal Design 4R-0L-4C W,S Prereq: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Capstone Design I 2R-3L-4C F, S Prereq: ES205, EM204, ME301, and Junior Standing

Students work in teams with three to five members on design projects furnished from clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in interim reports which are submitted to the clients.

ME 471 Capstone Design II 1R-4L-4C F, W Prereq: ME 470

This course is a continuation of ME470. Students continue work in teams with three to five members developing the project started in ME470. The emphasis is on detailing design solutions identified in the first quarter. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in interim reports which are submitted to the clients. This course is intended to be taken in the quarter immediately following ME470.

ME 472 Capstone Design III 1R-4L-4C W,S Prereq: ME 471

This course is a continuation of ME 471. The student teams test their prototype solutions and transfer the project results to their client. Continuous and regular communication with the outside clients, as well as with the faculty advisors, is expected. The course culminates with a final report that documents the design process. This course

is intended to be taken in the quarter immediately following ME471.

ME 480 Machine Component Design 4R-0L-4C S & F Prereq: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Completion of freshman and sophomore course requirements and approval of adviser and course instructor

Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Senior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged

Topics of current interests in mechanical engineering.

ME CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

ME 501 Advanced Thermodynamics 4R-0L-4C F Prereq: ME 301 or equivalent

Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.

ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Prereq: ME 302

Course may be repeated for different heat transfer topics.

ME 503 Viscous Fluid Flow 4R-0L-4C Prereq: ME 401

Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.

ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Prereq: ES 205, MA 212

Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.

ME 506 Advanced Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.

ME 507 Applied Nonlinear Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liapunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.

ME 510 Gas Dynamics 4R-0L-4C F Prereq: ES 202

Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer.

ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Prereq: ES 205 and ME 323

Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

ME 512 Light Weight Structures 4R-0L-4C S Prereq: MA 212 and EM 203 or EM 204

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

ME 513 Environmental Noise 4R-0L-4C F Prereq: Senior class standing

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

ME 518 Advanced Kinematics 4R-0L-4C S Prereq: ME 403

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ECE 519, EP 511, and CHE 519.

ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Prereq: EM 104 and Senior class standing

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

ME 522 Advanced Finite Element Analysis 4R-1L-4C S Prereq: ME 422

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

ME 526 Turbomachinery 4R-0L-4C Prereq: ES 205 or equivalent, or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency. Students enrolled in ME 526 must complete a design project including complexities not covered in ME 426. Students may not receive credit for both ME 426 and ME 526

ME 527 Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution. Students enrolled in ME527 must complete a design project not covered in ME 427. Students may not receive credit for both ME 427 and ME 527.

ME 536 Computational Intelligence in Control Engineering 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Machine learning and adaptation applied to feedback control, guidance and navigation. Neural Networks for pattern recognition, modeling and control. Radial basis function model identification by recursive least squares. Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.

ME 547 Visualizing Data 4R 0L 4C. Prereq: Graduate standing and instructor consent.

Same as ME 447 with the added requirement that the course is open only to graduate students having a graduate project or thesis generating quantitative data that the course instructor has agreed meets the 500 level course objectives.


ME 550 Combustion 4 R-0L-4C Prereq: ME 301

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises. Students enrolled in ME 550 must complete a design project not covered in ME 450. Students may not receive credit for both ME 450 and ME 550.

ME 590 Thesis Research F,W,S

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S

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Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Prereq: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

MDS 402 Seminar in Sustainability 2R-0L-2C Pre: Junior class standing and approval of certificate advisors
Provides students with the opportunity to examine, analyze, and reflect upon sustainability and sustainable engineering projects. Course work includes weekly readings and discussions, individual essays, and in-class and public presentations. Enrollment is open to all students, with first priority given to those pursuing the Certificate in Sustainability Studies. Permission to enroll is contingent upon students' previous sustainability project experience (curricular and / or co-curricular) as approved by certificate advisors.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Optical Engineering

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

Introduce students to basic knowledge of optics, principles and operation of a camera, shutters, films, and film development, color photography. Basic understanding of interference of waves, concept of holography, properties of various holograms, application of holography, and each student makes an individual hologram that can be seen in sunlight.

Light, optics, image formation, and optical instruments. Introduction to the properties, physics of operation, types and applications of lasers. Characteristics of optical fibers and optical communication systems. Applications of lasers and fibers in industry, medicine, and consumer products. Laser safety.

First-order optics including graphical ray tracing, Gaussian methods, y-nu ray tracing, cardinal points, apertures, stops, pupils, vignetting, and obscuration. Optical invariant, dispersion, chromatic aberrations, glass selection, exact ray tracing, third-order monochromatic aberrations, introduction to computer-aided design and analysis. Relevant laboratory experiments.

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with the faculty member for the research project prior to registering for this course.

Optical radiation, radiometry, and photometry. Blackbody radiation and thermal sources. Introduction to optoelectronic devices. Light emitting diodes and other optical sources. Optical detectors (thermal, photoemissive, and semiconductor detectors). Sources/effects of noise and SNR. Flux transfer in optical systems. Relevant laboratory experiments.

Electromagnetic waves in dielectrics/metals and complex refractive index. Optical, thermal, and mechanical properties of materials. Thin film interference, optical coatings, and design of multilayer films. Optical characterization of materials. Electromagnetic waves in anisotropic materials, double refraction, optical activity, and polarization devices.

Propagation of light and scalar diffraction theory. Fraunhofer and Fresnel diffraction, coherence, Fourier series and transforms, convolution and correlation. Linear system theory, impulse and step response, transfer functions. Coherent and incoherent image formation, optical transfer function (OTF), modulation transfer function (MTF). Image quality assessment methods. Optical information processing applications.

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Biology & Biomedical Engineering
Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

OE 393 Fiber Optics and Applications 3.5R-1.5L-4C W (every other year) Prereq: OE 295 & PH 316 or ECE 341 or consent of instructor

Basic dielectric waveguide equations; wave optics and ray optics; step-index and graded-index fibers; single mode and multi-mode fibers; mode cutoff conditions; numerical aperture; fabrication of optical fibers; fiber measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems. Relevant laboratory experiments.

OE 395 Optomechanics & Optical Engineering Lab 2R-6L-4C F Prereq: PH 292, OE 280, and OE 295

Design, assembly, and alignment of bench top optical systems. Introduction to experimental techniques in optics. Data collection and analysis. Relevant lecture topics including principles of opto-mechanical design, fold mirrors and prisms, lens and mirror mounting, kinematic mounts, precision adjustments and control.

OE 415 Optical Engineering Design I 2R-6L-4C S Prereq: OE 280 or EP 280 and JR/SR standing Coreq: RH 330

Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415.

OE 416 Optical Engineering Design II 2R-6L-4C F Prereq: OE 415

Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE 417 Optical Engineering Design III 2R-6L-4C W Prereq: OE 416

Continuation of OE 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with EP 417.

OE 434 Non-Imaging Optics 4R-0L-4C S (every other year) Prereq: OE 295

Lighting, illumination, and solar concentration systems. Radiometry and photometry for illumination, etendue, and concentration. Color coordinates, color vision, and color measurements. Sources, light transfer components, and systems evaluation. Introduction to design methods (edge-ray, compound parabolic concentrator, tailored reflector). Design examples and case studies.

OE 435 Biomedical Optics 4R-0L-4C W Prereq: PH 113 and MA 212

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Cross-listed with BE 435.

OE 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments. Cross-listed with ECE 480.

OE 450 Laser Systems and Applications 3.5R-1.5L-4C S Prereq: PH 292 and MA 212

Ray transfer matrix methods, Gaussian beam propagation, and beam quality. Optical resonators and stability, longitudinal and transverse modes. Stimulated emission, population inversion, rate equations, gain and threshold. Q-switching and mode-locking. Applications and types of lasers. Laser safety and relevant laboratory experiments.

OE 470 Special Topics in Optical Engineering 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in optics.

OE 480 Optical System Design 4R-0L-4C F Prereq: OE 280

Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based optimization, tolerancing, and manufacturing considerations.

OE 490 Directed Research Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S (every other year) Prereq: OE 393

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments.

OE 495 Optical Metrology 3.5R-1.5L-4C W Prereq: OE 280 and OE 392

Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

OE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Prereq: GR standing

Introduction to optics for incoming graduate students. Geometric optics; wave optics; sources and detectors. Students progressing towards or holding a bachelor's degree in Optical Engineering may not receive credit for OE 520.

OE 535 Biomedical Optics 4R-0L-4C W Prereq: PH 113, MA 212, and SR standing or GR standing

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 435 and OE 535. Cross-listed with BE 535.

OE 537 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 120 or ME 123 and SR standing or GR standing.

Introduction to image segmentation and recognition. Use of neural networks, fuzzy logic and morphological methods for feature extraction. Advanced segmentation, detection, recognition and interpretation. Relevant laboratory experiments and required project. Cross-listed with ECE 582.

OE 570 Special Topics in Optics 2 or 4C F, W, S Prereq: Consent of instructor and SR or GR standing

Lectures on contemporary topics in optical science, optical engineering, and photonics.

OE 580 Optical System Design 4R-0L-4C F Prereq: OE 280 and SR standing or GR standing

Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based optimization, tolerancing, and manufacturing considerations. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 480 and OE 580.

OE 585 Electro-Optics and Applications 3R-3L-4C W Prereq: PH 292, PH 316 and SR standing or GR standing

Optical wave propagation in anisotropic media. Normal surface and the index ellipsoid. Double refraction. Optical activity and Faraday rotation. Pockels and Kerr effects. Electrooptic modulators. Acousto-optic effect. Modulators and scanners. Introduction to nonlinear optics. Second-harmonic generation and frequency doubling. Relevant laboratory experiments.

OE 592 Fourier Optics and Applications 3.5R-1.5L-4C W Prereq: OE 392 and SR standing or GR standing

Two-dimensional linear systems. Scalar diffraction theory, Fresnel & Fraunhofer diffraction. Coherent optical systems analysis. Frequency analysis of optical imaging systems. Spatial filtering and analog optical information processing. Wavefront reconstruction and holography. Relevant laboratory experiments.

OE 593 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S (every other year) Prereq: OE 393 and SR standing or GR standing

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties, dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 493 and OE 593.

OE 594 Integrated Optics 4R-0L-4C F Prereq: OE 393 and SR standing or GR standing

Theory of dielectric optical waveguides. Waveguide modes. Coupled-mode formalism and periodic structures. Input and output coupling of optical beams to planar structures. Waveguide losses. Phase, frequency and polarization modulators. Waveguide gratings, electro-optic modulators, and switching. Applications of integrated optics.

OE 595 Optical Metrology 3.5R-1.5L-4C W Prereq: OE280, OE392 or SR/GR standing or consent of instructor; Coreq OE480

Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 495 and OE 595.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

Accelerated Math Physics Program - MA113, PH111, PH112 12R-3L-13C Prereq: One year of college level calculus (BC Calculus or equivalent), one year of high school physics, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Accelerated Math Physics Program Selection Committee.

A 5-week intensive immersion into calculus and physics which covers the equivalent of Calculus III, and Physics I, II. Taught only to incoming freshman who have demonstrated outstanding ability in both calculus and physics. Review of single variable calculus, both differential calculus and integral calculus, as needed. Covers from MA113: vectors and parametric equations in three dimensions, functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems with applications of vectors, parametric equations, partial derivatives and multiple integrals. Covers from PH111, PH112: kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, conservation of energy and momentum, torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, with relevant laboratory experiments.

PH 090 College Preparatory Physics 4R-0L-4C Prereq: College Algebra II
Topics covered include: Units, significant figures, vectors, 1 and 2 dimensional motion; kinematic equations, objects in free-fall, motion in a circle, projectile motion, Newton's Laws, contact forces, non-contact forces: gravity, Coulomb's Law, magnetic force; centripetal force; collisions, linear momentum, rotational kinematics, torques, angular momentum, mechanical equilibrium - static equilibrium. The credits from this course cannot be counted toward any degree completion at Rose-Hulman.

PH 111 Physics I 3.5R-1.5L-4C F,W Coreq: MA 111
Kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, strong and weak nuclear forces, conservation of energy and momentum, relevant laboratory experiments.

PH 112 Physics II 3.5R-1.5L-4C W,S,F Prereq: PH 111 and MA 111; Co: MA 112
Torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, relevant laboratory experiments.

PH 113 Physics III 3.5R-1.5L-4C S,F,W Prereq: PH 112 and MA 112; Coreq: MA 113
Sources of magnetic fields, Faraday's law, inductance electromagnetic waves, reflection and polarization, geometric and physical optics, introduction to relativity, relevant laboratory experiments.

PH 200 Career Preparation 1R-0L-1C W,S
This course is for physics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, MA200 and SV200.

PH 215 Introduction to CHAOS 2R-0L-2C W
What constitutes chaotic behavior, detection of chaos in real systems using phase space plots, Poincare

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

sections, bifurcation plots, power spectra, Lyapunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Prereq: MA 111, and PH 111 or EM 120

Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Prereq: PH 111 or Coreq: EM 202; and Coreq: MA 112

Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Prereq: MA 111, and PH 111 or EM 120

Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Prereq: MA 111 and PH 111 or EM 120

Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Prereq: PH 113 and Coreq: MA 211

Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Prereq: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Prereq: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Prereq: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Prereq: PH 113

The wave equation; electromagnetic waves; phase and group velocities; complex refractive index; dispersion, interference; interferometers and applications, optical interferometry; coherence; polarized light; Jones vectors/matrices; production of polarized light; birefringence, Fraunhofer diffraction; diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Prereq: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Prereq: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S Arranged Prereq: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W Arranged Prereq: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Prereq: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Prereq: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Prereq: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Prereq: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication, transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Prereq: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Prereq: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schroedinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schroedinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Prereq: PH 113 and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Cross-listed with PH 505.

PH 407 Solid State Physics 4R-0L-4C S (even years) Prereq: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 410 General Relativity 4R-0L-4C W (odd years) Pre: PH 310 and MA 421

An in-depth study of Einstein's theory of General Relativity. Gravity as geometry and curved space-time, metrics, and geodesics. Orbits and light paths around spherical masses. Detailed study of Einstein's equation in vacuum and with sources of space-time curvature.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Prereq: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Prereq: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Prereq: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must

make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

PH CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Prereq: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Prereq: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Prereq: Consent of instructor

Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.



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Spring Term		Credit
BIO 230	Eukaryotic Cell & Molecular Biology	4
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
PH 113	Physics III	4
MA 223	Engineering Statistics	4
Total		16

Junior Year

Fall Term		Credit
BIO 320	Ecology	4
CHEM 330	Biochemisty	4
HSS	Elective	4
BIO 399	Practice of Science	4
Total		16

Senior Year

Fall Term		Credit
BIO 498	Senior Thesis Research III	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16

Winter Term		Credit
BIO 330	Evolutionary Biology	4
BIO 496	Senior Thesis Research I	2
BIO	Elective	4
HSS	Elective	4
Total		14

Winter Term		Credit
BIO 499	Senior Thesis Research IV	2
	Science/Technical Elective	4
BIO	Elective	4
HSS	Elective	4
Total		14

Spring Term		Credit
BIO 310	Plant Structure & Function	4
BIO 497	Senior Thesis Research II	4
SV 304	Bioethics	4
HSS	Elective	4
Total		16

Spring Term		Credit
BIO	Elective	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16
Total credits required:		188

A BIO science/technical elective is any Rose-Hulman course that has a prefix of BIO, BE, CHEM, CHE, CE, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required BIO courses	52 credits
BIO electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	12 credits
Required MA, CHEM, PH	63 credits
Required CLSK	1 credit
Sci/Tech electives	12 credits
Required BE course	4 credits
Total	188 credits

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology

requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required Courses

Elective Courses

Choose 12 credits* from the following courses:

Course	Description	Hours
CHEM 111, 113, 115	General Chemistry	12
CHEM 251, 252, 253	Organic Chemistry	9
CHEM 251L, 252L, 253L	Organic Chemistry Lab	3
CHEM 330, 430, 433	Biochemistry	9
CHEM 361, 362 or CHEM 360 and CHE 303, 304	Physical Chemistry	8
BIO 110, 120, 130	Biology	12
BIO 210	Genetics	4
BIO 220, 230	Molecular Biology	8
BIO 411	Genetic Engineering	4
Total		69

Course	Description
BIO 330	Evolutionary Biology
BIO 421	Microbiology
BIO 431	Genomics and Proteomics
BIO 441	Virology
BIO 451	Cancer Biology
BIO 492	Directed Study in Biology
CHEM 225	Analytical Chemistry
CHEM 291	Introduction to Research
CHEM 331	Biochemistry II
CHEM 431	Biochemical Instrumentation
CHEM 451	Organic Structure Determination
CHEM 290 or CHEM 490	Chemical Research
PH 302	Biophysics

Total Credits for Second Major 81

**Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the BIO electives listed, and 4 credits chosen from any BIO or BE course.*

STUDENTS WITH A MAJOR IN BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above BIO course (total: 29 hours required beyond Biology major).

Biology Minor

Biology is an exciting subject that has applications relevant to all other fields of study at the Institute. Students who are interested in enriching their major area of study with a knowledge of life sciences can do so with the Biology Minor. With proper course selection, the Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Minor in Biology has the following requirements.

1. All students must complete BIO110 (Cell Structure and Function) or BIO130 (Evolution and Diversity) and four more courses in biology (BIO) or allied areas, above those courses already specifically required to fulfill the student's major, subject to the following requirements:
 - a. At least three of the four electives must be BIO courses.
 - b. At least three of the electives must be 200-level or above.
2. Students electing to pursue the Area in Biology must follow a plan of study that is approved by the Minor Advisor. Current advisor information and a form for the planning and approval of a minor can be obtained from the BBE Department Secretary.
3. Allied area courses could include:

BE310	Analysis of Physiological Systems I	IA236	Communicating STEM to a Public Audience
BE320	Analysis of Physiological Systems II	IA239	Rhetoric of Science
BE570	Intro to Tissue Engineering	IA401	Philosophy of Science
BMTH310	Mathematical Biology	IA471	Computational Psychology
BMTH311	Systems Biology	MA482/BE482	Bioengineering Statistics
BMTH312	Bioinformatics	ME447	Visualizing Data
BMTH413	Computational Biology	PH302	Biophysics
CE460	Intro to Environmental Engineering	SV304	Bioethics
CHE545	Intro to Biochemical Engineering	SV371	Social Psychology
CHEM264	Intro to Environmental Science	SV373	Abnormal Psychology
CHEM330	Biochemistry	SV472	Studying Human Behavior
CHEM430	Advanced Biochemistry	SV386	Human Evolution

Additional courses not listed here can be considered on a case-by-case basis.

Biochemistry & Molecular Biology Minor

Completion of BIO110, CHEM111, CHEM113 and CHEM115. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

Course	Description
BIO 210	Mendelian and Molecular Genetics
BIO 220	Prokaryotic Cell and Molecular Biology
or	
BIO 230	Eukaryotic Cell and Molecular Biology
BIO 411	Genetic Engineering
or	
BIO 431	Genomics and Proteomics
CHEM 230	Introduction to Organic Chemistry and Biochemistry
or	
CHEM 251	Organic Chemistry I
and	
CHEM 252	Organic Chemistry II
CHEM 330	Biochemistry
CHEM 430	Advanced Biochemistry
with	
CHEM 433	Biochemistry Laboratory

Biology is an exciting subject that has applications relevant to all other fields of study at the Institute. Students who are interested in enriching their major area of study with a knowledge of life sciences can do so with the

Biology Minor. With proper course selection, the Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

BIOCHEMISTRY PLAN OF STUDY

Freshman Year

Fall Term		Credit
CHEM 111*	General Chemistry I	4
MA 111	Calculus I	5
BIO 110	Cell Structure & Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		18

Winter Term		Credit
CHEM 113*	General Chemistry II	4
MA 112	Calculus II	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		17

Spring Term		Credit
CHEM 115	General Chemistry III	4
MA 113	Calculus III	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
PH 113	Physics III	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
BIO 210	Mendelian & Molecular Genetics	4
Total		16

Winter Term		Credit
CHEM 200	Career Preparation	1
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
CHEM 291	Intro to Undergraduate Research	4
MA 381	Introduction to Probability with Applications to Statistics	4
BIO 220	Prokaryotic Cell & Molecular Biology	4
Total		16

Spring Term		Credit
CHEM 253	Organic Chemistry III	3

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

CHEM 253L	Organic Chemistry III Lab	1
CHEM 225	Analytical Chemistry	4
BIO 230	Eukaryotic Cell & Mol. Biology	4
RH 330 (or HSS)	Technical Communication	4
Total		16

Junior Year

Fall Term		Credit
CHEM 326	Bioanalytical Chemistry	4
CHEM 330	Biochemistry I	4
CHEM 361	**Physical Chemistry I	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 395	Chemistry Seminar	0
CHEM 490	Research	1
HSS (or RH330)	Elective	4
Total		17 or 18

Winter Term		Credit
CHEM 327	Advanced Analytical	4
CHEM 362	**Physical Chemistry II	4
CHEM 331	Biochemistry II	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

Spring Term		Credit
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 430	Advanced Biochemistry	4
CHEM 433	Biochemistry Lab	1
HSS	Elective	4
CHEM 490	Research	1
Total		14 or 15

Senior Year

Fall Term		Credit
CHEM 441	Inorganic Chemistry I	4
CHEM 495	Chemistry Seminar	0
CHEM 490	Chemistry Research	1
CHEM 491	Research Thesis (F, W or S)	1
##Advanced Chemistry or Biochemistry Elective		4
Advanced Biology Elective		4
Free Elective		4
Total		17 or 18

Winter Term		Credit
CHEM 496	Chemistry Seminar	0
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
##Advanced Biology, Chemistry, Biochemistry Elective		4
Free Elective		4
Total		12, 13, or 14

Spring Term		Credit
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Free Elective		4
Free Elective		4
Total		12, 13, or 14
Total credits required:		192

Notes: Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441	4
Biochemistry	330, 331, 430, 433	13
Research	291, 490	8
Chemical Communication	400, 401, 402, 403	4
Career Preparation	200	1
Electives		8
Total		86

Summary of minimum graduation requirements:


Course or areas	Required	Elective	Total
Chemistry	78	8	86
Physics	12	0	12
Mathematics	23	0	23
Biology	20	0	20
Humanities and Social Sciences	4	32	36
Electives	0	16	16
College and Life Skills	1	0	1
Total	136	56	194

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM111	General Chemistry I	4
CHEM113	General Chemistry II	4
CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		32

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors
Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	4
or CHEM253	Organic Chemistry III	
CHEM330	Biochemistry I	4
or CHEM361	Physical Chemistry I	
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24



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Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Biomathematics

Much of biology incorporates the mathematical and computational sciences. The biomathematics degree blends mathematics, biology, and computer science in preparation for careers in the quantitative life sciences and for continued graduate studies. The degree's mission is to provide a world class undergraduate education in applied mathematics in support of the life sciences.

- Biological data is being generated with unprecedented precision and in unfathomable volumes.
- Quantifying biological observations requires mathematical and statistical analysis.

The basic principles of complex biological systems support mathematical and computational modeling, which can lead to testable hypotheses and new discoveries.

The biomathematics degree will provide a broad based undergraduate experience that 1) prepares students with a rigorous education in applied mathematics, 2) educates students in the fundamental principles of biology, 3) trains students to work in a computational arena, 4) introduces students to several of the sister disciplines of computational biology, mathematical biology, bioinformatics, systems biology, and biostatistics, and 5) guides students through an advanced undergraduate research project. The degree will also liberally educate students through the study of the humanities and social sciences. Students of the program will be encouraged to participate in external and internal research programs and industrial internships and/or co-ops.

Graduates will be prepared for graduate study in any of the sister fields as well as for careers in the quantitative life sciences. Each graduate will complete a capstone research experience that will culminate in a written report and a public presentation.

Freshman Year

Fall Term		Credit
BIO 110	Cell Structure and Function	4
CHEM 111	General Chemistry	4
MA 111	Calculus I	5
RH 131	Rhetoric and Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term		Credit
PH 111	Physics I	4
CHEM 113	General Chemistry II	4
MA 112	Calculus II	5
HSS		4
Total		17

Sophomore Year

Fall Term		Credit
BIO 210	Mendelian & Molecular Genetics	4
MA 211	Differential Equations	4
CSSE 120	Intro. to Software Devel.	4
PH 113 or CHEM 251	Add'l Science	4
Total		16

Winter Term		Credit
BIO 220	Microbiology	4
MA 212	Matrix Algebra & Systems of D.E.	4
MA 381	Intro. to Probability	4

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

<i>Spring Term</i>		<i>Credit</i>
BIO 130	Evolution and Diversity	4
PH 112	Physics II	4
MA 113	Calculus III	5
HSS		4
Total		17

HSS		4
MA 200	Career Preparation	1
Total		17
<i>Spring Term</i>		<i>Credit</i>
BIO 230	Cell Biology	4
MA 371	Linear Algebra	4
HSS		4
Elective*		4
Total		16

Junior Year

<i>Fall Term</i>		<i>Credit</i>
BMTH 310	Mathematical Biology	4
MA 382	Intro. to Statistics w/Prob	4
HSS		4
Elective*		4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
BMTH 496	Capstone Experience I	2
HSS		4
Elective*		4
Elective*		4
Total		14

<i>Winter Term</i>		<i>Credit</i>
BMTH 311	Systems Biology	4
MA 332	Intro to Computational Sci.	2
RH 330	Technical & Profess. Comm.	4
Elective*		4
Total		16

<i>Winter Term</i>		<i>Credit</i>
BMTH 497	Capstone Experience II	4
Elective*		4
Elective*		4
Elective*		4
Total		16

<i>Spring Term</i>		<i>Credit</i>
BMTH 312	Bioinformatics	4
HSS		4
Elective*		4
Elective*		4
Total		16

<i>Spring Term</i>		<i>Credit</i>
BMTH 413	Computational Biology	4
BMTH 498	Capstone Experience III	2
Elective*		4
Elective*		4
Total		14
Total credits required:		193

- *Requirements: 3 Free Electives 12 hours
- 3 MA Electives 12 hours
- 5 Tech Electives 20 hours
- 1 Domain Elective 4 hours

SUMMARY OF GRADUATION REQUIREMENTS

HSS		36 hours
CLSK	CLSK 100	1 hour
Math Core	MA 111, 112, 113, 200, 211, 212, 332, 371 or 373, 381, and 223 or 382	40 hours
Biomath Core	Four BMTH courses numbered 300 or above	16 hours
Basic Science	BIO 110, 130, 120 or 210, 220, and 230	40
	CHEM 111, 113	hours
	PH 111, 112	
	one of CHEM 251 or PH 113	
Computer Science	CSSE 120	4 hours
Capstone Experience	BMTH 496, 497, 498	8 hours
Domain Elective	Any of the following, with no course substitutions permitted. BIO 330 Evolutionary Biology 4R-0L-4C W Prereq. BIO 130	4 hours

CHEM 330 Biochemistry I 4R-0L-4C W Prereq. CHEM 252
CSSE 304 Programming Language Concepts 4R-0L-4C W Prereq. CSSE
230 and MA 275
MA 366 Functions of a Real Variable 4R-0L-4C W Prereq. MA 275 and MA
113

Math Electives	Any mathematics course numbered 300 or above, or MA 275	12 Hours
Technical Electives	Non-mathematics courses numbered 200 or above in the physical sciences, life sciences, computer science, or engineering	20 Hours
Free Electives		12 Hours
Total		193 hours

SECOND MAJOR IN BIOMATHEMATICS

The second major in biomathematics is open to all majors with the following requirements and restrictions.
Eligibility and limitations

- The MA/BMTH double major must be seperated by at least 24 hours.

REQUIREMENTS (72 HOURS)

Math Core	MA 211, 332, 371 or 373, 381, and 223 or 382	20 hours
Biomath Core	any four BMTH courses numbered 300 or above	16 hours
Math Electives		12 hours
Biology	BIO 110 and three courses from different categories described below BIO 130 BIO 120 or 210 BIO 205 or 230 BIO 220	16 hours
Senior Capstone Experience	BMTH 496, 497, 498	8 hours

MINOR IN BIOMATHEMATICS

A minor in biomathematics is open to all students.

REQUIREMENTS (47 HOURS)

Math Core	MA 111, 112, 113, 211, 212, and 223 or 382	27 hours
Biomath Core	any three BMTH courses numbered 300 or above	12 hours
Biology	BIO 110 and one of BIO 205, 210, 220, 230	8 hours

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

- be able to design and conduct experiments, making measurements from both living and non-living systems.
- be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- be able to function in multidisciplinary teams in different roles.
- be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- have the skills required for self-learning.
- be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit
BIO 110	Cell Structure and Function	4
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
EM 104	Graphical Communication	2
Total		16

Winter Term		Credit
BIO 120	Comparative Anatomy & Physiology	4
PH 112	Physics II	4
MA 112	Calculus II	5
EM 121	Statics and Mechanics of Materials I	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
RH 131	Rhetoric & Composition	4
MA 113	Calculus III	5
BE 100	Problem Solving in the Biological Sciences and Engineering	4
Total		17

Junior Year

Fall Term		Credit
HSS	Elective	4
BIO 205	Cellular Physiology	4
	Tech & Profess'l Comm	4

Sophomore Year

Fall Term		Credit
ES 201	Conservation & Accounting Principles	4
CHEM 111	General Chemistry I	4
MA 211	Differential Equations	4
ES 203	Electrical Systems	4
Total		16

Winter Term		Credit
ES 202	Fluid and Thermal Systems	3
ES 204	Mechanical Systems	3
MA 212	Matrix Algebra and Systems of Differential Equations	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		18

Spring Term		Credit
BE 201	Biomedical Measurements	4
BIO 130	Evolution and Diversity	4
ES 205	Analysis & Design of Engineering Systems	4
MA 223	Engineering Statistics	4
Total		16

Senior Year

Fall Term		Credit
BE 410	Biomedical Engineering Design I	4
HSS	Elective	4

HSS or RH330	or HSS Elective	
EM 204	Statics and Mechanics of Materials II	4
Total		16
Winter Term		Credit
BE 310	Physiological Systems I	4
BE 331	Biomechanics	3
BE 351	Biomedical Engineering Lab	2
BE 361	Biomaterials	3
HSS or RH330	HSS Elective or Tech & Profess'l Comm	4
Total		16
Spring Term		Credit
SV 304	Bioethics	4
BE 320	Physiological Systems II	4
BE 390	Principles of Biomedical Engineering Design	2
BE	Area	4
Total		14

	Free Elective	4
BE	Area Elective	4
Total		16
Winter Term		Credit
BE 420	Biomedical Engineering Design II	4
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
Total		16
Spring Term		Credit
BE 430	Biomedical Engineering Design III	2
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
Total		14
Total credits required:		192

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the BBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 417	Advanced Materials
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanics
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both
**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols

BE 516	Introduction to MEMS
BE 435/535	Biomedical Optics
BE 555	Electrophysiology
ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course	Title
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
BE 525	Biomedical Fluid Mechanics
BE 531	Biomechanics II
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopaedic Biomechanics
BE 550	Research Methods in Biomechanics
EM 403	Advanced Mechanics of Materials
ME 422	Finite Elements for Engineering Applications
ME 520	Computer-Aided Design and Manufacturing
ME 522	Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Minor

The biomedical engineering minor is intended to provide a biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and healthcare related fields.

In order to complete the requirements of the biomedical engineering minor, a student must complete either IO 110-Cell Structure & Function or BIO 120-Comparative Anatomy & Physiology AND complete four courses from the list shown below. Other BE courses may be substituted with approval by the BBE Department Head. At least three of the courses must have a BE prefix.

BIO411	Genetic Engineering
BE310	Analysis of Physiological Systems I
BE320	Analysis of Physiological Systems II
BE331 and BE352	Biomechanics and Biomechanics Lab
BE340 *	Biomedical Signal Processing *

BE350 **	Biocontrol Systems **
BE361 and BE353	Biomaterials and Biomaterials Lab
BE435/535	Biomedical Optics
BE/MA482	Bioengineering Statistics
BE520	Introduction to Brain Machine Interfaces
BE525	Biomedical Fluid Mechanics
BE531	Biomechanics II
BE534	Soft Tissue Mechanics
BE539	Multiscale Biomechanics
BE543	Neuroprosthetics
BE545	Orthopaedic Biomechanics
BE560	Tissue-Biomaterial Interactions
BE570	Introduction to Tissue Engineering

* BE340 cannot be used for a BE minor by students majoring in electrical or computer engineering.
** BE350 cannot be used for a BE minor by students who have taken ECE320 or ME406.

In addition to courses in the above area concentration, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:


BE201	Biomedical Instrumentation and Measurements
EM121	Statics & Mechanics of Materials I
EM204	Statics & Mechanics of Materials II
EM301	Fluid Mechanics
ECE180	Introduction to Signal Processing
ECE203 *	DC Circuits
ECE204	AC Circuits
ES201	Conservation & Accounting Principles
ES202	Fluid Systems
ES203 *	Electrical Systems
ES204	Mechanical Systems
CHE201	Conservation Principles and Balances

CHE202 Basic Chemical Process Calculations

CHE301 Fluid Mechanics

* Students may use either ECE203 or ES203 for a BE minor, but not both of these courses.

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the head of the Department of Biology and Biomedical Engineering.



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

- Our graduates will attain a promotion and/or responsibilities beyond their entry-level position, or progress toward the completion of an advanced degree.
- Our graduates will continue to develop professionally.
- Our graduates will collaborate professionally within or outside of their organizations at a regional, national and/or international level.
- Our graduates will participate in service to their professions and/or community organizations.

Student Outcomes

Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

11. A knowledge of contemporary issues

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4
Total		14

Winter Term		Credit
CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5
PH 111	Physics I	4
HSS	Elective	4
Total		17

Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Freshman Year (A2 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4
Total		14

Winter Term		Credit
CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5
PH 111	Physics I	4
HSS	Elective	4
Total		17

Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Sophomore Year (A1 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4
HSS	Elective	4

Sophomore Year (A2 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4
HSS	Elective	4

Total		16
<i>Winter Term</i>		<i>Credit</i>
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
HSS	Elective	4
Total		16

Junior Year (A1 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
CHE 315	Materials Science	4
CHEM 225	Analytical Chemistry I	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CHE 321	Applications of Heat and Mass Transfer	4
CHEM 360	Intro Physical Chemistry	4
MA 223	Engineering Statistics I	4
RH 330	Technical and Professional Communication	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CHE 404	Kinetics & Reactor Design	4
CHE 411	Chemical Engineering Lab I	3
ECE 206	Elements of Electrical Engineering	4
	Elective (Free)	4
Total		15

Senior Year (A1 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4
CHE 416	Design I	4

Total		16
<i>Winter Term</i>		<i>Credit</i>
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
MA 223	Engineering Statistics I	4
CHEM 225	Analytical Chemistry I	4
HSS	Elective	4
CHE 315	Materials Science	4
Total		16

Junior Year (A2 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
RH 330	Technical and Professional Communication	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CHE 321	Applications of Heat and Mass Transfer	4
CHE 411	Chemical Engineering Lab I	3
CHEM 360	Intro Physical Chemistry	4
	Elective (Free)	4
Total		15

Senior Year (A2 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 404	Kinetics & Reactor Design	4
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4

Free Elective(Free)		4	CHE 416	Design I	4
Free Elective(CHE)		4		Free Elective(Free)	4
Total		17		Total	17
Winter Term			Winter Term		Credit
CHE 413	Chemical Eng. Lab III	4	CHE 413	Chemical Eng. Lab III	4
CHE 417	Design II	4	CHE 417	Design II	4
CHE 440	Process Control	4	CHE 440	Process Control	4
HSS	Elective	4	HSS	Elective	4
Total		16	Total		16
Spring Term		Credit	Spring Term		Credit
CHE 418	Design III	2	CHE 418	Design III	2
HSS	Elective	4	HSS	Elective	4
HSS	Elective	4		Elective(CHE)	4
	Elective(Approved)	4		Elective(CHE)	4
	Elective(CHE)	4		Elective(Approved)	4
Total		18	Total		18
Total credits required:		194	Total credits required:		194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 405 Introduction to MEMS: Fabrication and Applications
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 320 Fundamentals of Heat and Mass Transfer
- CHE 321 Applications of Heat and Mass Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- BIO110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- BIO210 - Mendelian and Molecular Genetics
- BIO220 - Microbiology
- or
- BIO230 - Cell Biology
- BIO411 - Genetic Engineering
- BIO421 - Applied Microbiology
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary. Students interested in the Biochemical Engineering area minor should consult the CHE Department head and receive prior approval for any equivalent courses to be considered.

AREA OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. Students may not count courses towards a concentration that also count towards another concentration or towards a minor, certificate, double major, or second degree. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with prior approval by the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 450 Combustion

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT562 Risk Analysis and Management
- EMGT581 Multi-objective Optimization
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include biology, chemical engineering and mathematics.

CHEMISTRY PLAN OF STUDY

Freshman Year

Fall Term		Credit
CHEM 111*	General Chemistry	4
MA 111	Calculus I	5
BIO 110**	Cell Structure and Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		18

Winter Term		Credit
CHEM 113*	General Chemistry II	4
MA 112	Calculus II	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		17

Spring Term		Credit
CHEM 115	General Chemistry III	4

Sophomore Year

Fall Term		Credit
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
PH 113	Physics III	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Free Elective	4
Total		16

Winter Term		Credit
CHEM 200	Career Preparation (take in winter or spring)	1
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
CHEM 291	Intro to Undergraduate Research	4
MA 381	Introduction to Probability with Applications to Statistics	4

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

MA 113	Calculus III	5
HSS	Elective	4
PH 112	Physics II	4
Total		17

Free Elective		4
Total		16 or 17
Spring Term		Credit
CHEM 200	Career Preparation (take in winter or spring)	1
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
CHEM 225	Analytical Chemistry I	4
HSS	RH 330	4
Free Elective		4
Total		16 or 17

Junior Year

Fall Term		Credit
CHEM 326	Bioanalytical Chemistry	4
CHEM 361	***Physical Chemistry I	4
CHEM 330	Biochemistry I	4
CHEM 391	Research Proposal (F,W or S)	1
CHEM 395	Chemistry Seminar	0
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

Winter Term		Credit
CHEM 327	Advanced Analytical	4
CHEM 362	***Physical Chemistry II	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 490	Research	1
HSS	Elective	4
Free Elective		4
Total		17 or 18

Spring Term		Credit
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 451	Organic Structure Determination	4
HSS	Elective	4
Free Elective		4
CHEM 490	Research	1
Total		17 or 18

Senior Year

Fall Term		Credit
CHEM 441	Inorganic Chemistry I	4
CHEM 490	Research	1
CHEM 491	Research Thesis (F, W or S)	1
CHEM 495	Chemistry Seminar	0
CHEM 497	Research Presentation (F, W or S)	1
Chemistry Elective		4
Free Elective		4
Total		13, 14, or 15

Winter Term		Credit
CHEM 442	Inorganic Chemistry II	4
CHEM 491	Research Thesis (F, W or S)	1
CHEM 496	Chemistry Seminar	0
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Chemistry Elective (400-level)###		4
Total		12, 13, or 14

Spring Term		Credit
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Free Elective		4
Free Elective		4
Total		12, 13, or 14
Total credits required:		191

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM 111 General Chemistry I is an automatic substitution for the former CHEM 105 Engineering Chemistry I.

CHEM 113 General Chemistry II is an automatic substitution for the former CHEM 107 Engineering Chemistry II.

*BIO 120 or BIO 130 may be substituted for BIO 110

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Summary of minimum graduation requirements:

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441, 442	4
Biochemistry	330	4
Organic Structure Determination	451	4
Chemical Communication	400, 401, 402, 403	4
Research	291, 490	8
Career Preparation	200	1
Electives		8
Total		85

Course or areas	Required	Elective	Total
Chemistry	77	8	85
Physics	12	0	12
Mathematics	23	0	23
Biology	4	0	4
Humanities and Social Sciences	4	32	36
Electives	0	32	32
College and Life Skills	1	0	1
Total	121	76	193

Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in biology or chemical engineering are different from those majoring in other disciplines.

Minor in Chemistry for Most Students

Course Number	Course Title	Credits
CHEM 113	General Chemistry II	4
CHEM 115	General Chemistry III	4
CHEM 225	Analytical Chemistry	4
CHEM 251	Organic Chemistry I	4
CHEM 252	Organic Chemistry II	4
*Approved List of		4

Chemistry Electives	
Total	24

*Approved list of chemistry electives include CHEM 253, CHEM 290 (up to two credit hours), CHEM 291, or any 300 or 400 level chemistry courses.

Minor in Chemistry for Chemical Engineering and Biology Majors

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student's major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
CHEM 115	General Chemistry III	4
CHEM 225	Analytical Chemistry	4
CHEM 251	Organic Chemistry I	4
CHEM 264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHEM 465	Energy and the Environment	4
Total		32

Environmental Chemistry Minor for Chemical Engineers and Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
or CHEM 330	Biochemistry	4
CHEM 361	Physical Chemistry I	4
or CHE 303	Chemical Engineering Thermodynamics	4
CHEM 264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHE 465	Energy and the Environment	4
Total		24



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society's need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department's Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department's Program Educational Objectives and Student Learning Outcomes*

Program Educational Objectives

- I. Graduates will demonstrate the ability to perform **essential engineering functions** in the design, management, or construction industry.
- II. Graduates will demonstrate the ability to **design/construct complex engineering systems** in the broad-based engineering industry.
- III. Graduates will demonstrate their potential for **technical leadership and management**.

Student Learning Outcomes

1. **Technical Core** - Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
2. **Experiments** - Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.
3. **Engineering Problems** - Develop problem statements and solve well-defined engineering problems in

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

four technical areas appropriate to civil engineering.

- 4. **Engineering Impact** - Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- 5. **Contemporary Issues** - Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.
- 6. **Design** - Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- 7. **Multidisciplinary** - Function effectively as a member of a multidisciplinary team.
- 8. **Professional/Ethical** - Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- 9. **Communication** - Organize and deliver effective verbal, written, and graphical communications.
- 10. **Engineering Tools** - Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.
- 11. **Life Long Learning** - Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- 12. **Leadership** - Apply leadership principles to direct the efforts of a small group.
- 13. **Service** - Use one's time and skills to benefit an individual or community without cost to the recipient.
- 14. **Project Management** - Explain key concepts in project management, and develop solutions to well-defined project management problems.
- 15. **Business and Public Administration** - Explain key concepts and processes used in business, public policy, and public administration.
- 16. **Cultural and Global Awareness** - Analyze and interpret cultural perspectives and social systems that define human characteristics.

* The civil engineering program uses the term "educational objective" to describe the expected accomplishments of our students in three to five years following graduation. The term "student learning outcome" is used to describe knowledge and skills at the time of graduation.

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Civil Engineering PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
	or	
	Elective(HSS)	
CLSK 100	College & Life Skills	1
CE 101	Engineering Surveying	2
Total		16

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
RH 131	Rhetoric and Composition	4
	or	
	Elective(HSS)	
CE 111	Geographic Info Systems	2
EM 102	Graphical Communications	2
	for CE	
Total		17

Spring Term		Credit
MA 113	Calculus III	5
EM 103	Introduction to Design	2
EM 120	Engineering Statics	4
	Elective (HSS)	4
Total		15

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
CHEM 111	General Chemistry I	4
EM 202	Dynamics	4
HSS	Elective	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
EM 203	Mechanics of Materials	4
CHEM 113	General Chemistry II	4
CE 250	Sustainable CE Design	2
	Elective (Science)***	4
Total		18

Spring Term		Credit
MA 223	Statistics for Engineers	4
EM 301	Fluid Mechanics	4
CE 320	C.E. Materials	4
CE 380	Transportation Engineering	4
Total		16

Junior Year

Fall Term		Credit
CE 321	Structural Mechanics I	4
CE 336	Soil Mechanics	4
CE 205	Thermodynamics	4
	or	
CHE 201	Conservation Principles and Balances	
CE 371	Hydraulic Engineering	4
Total		16

Winter Term		Credit
ECE 206	Elements of Electrical Eng. or	4
CHE 202	Basic Chemical Process Calculations	
CE 441	Construction Engineering	2
CE 432	Concrete Design I	3
CE 471	Water Resources Engineering	4
	Elective (Science)***	4
Total		17

Spring Term		Credit
CE 310	Civil Engineering Numerical Methods	2
CE 431	Steel Design I	3
CE 460	Environmental Engineering	4
RH 330	Technical and Professional Communication	4
CE 461	Environmental Engineering Lab	2
Total		15

Senior Year

Fall Term		Credit
CE 486	C.E. Design & Synthesis I	2
CE	**C.E. Elective	4
CE 450	C.E. Codes & Regulations	4
HSS	Elective	4
HSS	Elective	4
Total		18

Winter Term		Credit
CE 487	Technical System Design & Synthesis	2
CE 488	C.E. Design & Synthesis II	2
CE	**C.E. Elective	4
	*Elective (Technical)	4
CE 303	Engineering Economy	4
Total		16

Spring Term		Credit
CE 489	C.E. Design & Synthesis III	2
	*Elective(Technical)	4
HSS	Elective	4
HSS	Elective	4
CE 400	Career Preparation Seminar	0
Total		14
Total credits required:		194

***A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, or physics.**
****Student shall choose any 400 or 500 level CE elective course, designated with the "CE" prefix, as a CE Elective, in consultation with their advisor.**
*****At least 4 hours of science elective must be in a natural science outside Chemistry or Physics.**

Environmental Engineering Minor

The Environmental Engineering minor includes 6 required courses and 8 elective credit hours. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their interests.


The 6 required courses are as follows:

CE 460	Introduction to Environmental Engineering
CE 471	Water Resources Engineering
CHEM 264	Introduction to Environmental Science
CE 563/CHE 461	Unit Operations in Environmental Engineering
CE 564	Aquatic Environmental Chemistry
CHEM 251	Organic Chemistry I
CHEM 251L	Organic Chemistry I Laboratory

And 8 credit hours from the following courses:

CE 561/CHE 450	Air Pollution Control
CE 562	Treatability Studies
CE 565	Solid and Hazardous Waste Regulation and Treatment
CE 566	Environmental Management
CE 567	Applied Hydrologic Modeling
CE 568	Applied Contaminant Transport Modeling
CE 569	Environmental Systems Optimization
CE 573	Groundwater Analysis
CE 590	Special Problems
CE 598	Stream Restoration (Environmental River Mechanics)
CHE 465	Energy and the Environment
CHE 470	Safety, Health, and Loss Prevention
BIO 320	Ecology and Environmental Biology

Advisor: Dr. Michael A. Robinson,
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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;
2. Function independently and in leadership positions within multidisciplinary teams;
3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;
4. Adapt and independently extend their learning to excel in fields about which they are passionate;
5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.

CPE student outcomes

At the time of graduation, students will have demonstrated:

1. an ability to apply knowledge of mathematics, science, and engineering
2. an ability to design and conduct experiments, as well as to analyze and interpret data
3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
4. an ability to function on multidisciplinary teams
5. an ability to identify, formulate, and solve engineering problems
6. an understanding of professional and ethical responsibility
7. an ability to communicate effectively
8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context
9. a recognition of the need for, and an ability to engage in life-long learning
10. a knowledge of contemporary issues
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The computer engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

COMPUTER ENGINEERING PLAN OF STUDY

Freshman Year		Sophomore Year	
Fall Term	Credit	Fall Term	Credit

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Intro to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
Total		17

Junior Year

Fall Term		Credit
MA 275	Discrete & Combinational Algebra I	4
CSSE 232	Computer Architecture I	4
ECE 380	Discrete-Time Signals	4
	or	
ECE 320	Linear Control Systems	
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
ECE 312	Communication Networks	4
HSS	Elective	4
CSSE 332	Operating Systems	4
	or	
CSSE 230	Data Structures and Algorithm Analysis	
	Math/Science Elective	4
Total		16

Spring Term		Credit
ECE 332	Computer Architecture II	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
Total		15

MA 211	Differential Equations	4
CHEM 111	General Chemistry I	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
Total		16

Spring Term		Credit
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
CSSE 220	Object Oriented Software Development	4
ECE 250	Electronic Device Modeling	4
Total		16

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
ECE 343	High Speed Digital Design	4
	Area Elective	4
HSS	Elective	4
Total		15

Winter Term		Credit
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
Total		16

Spring Term		Credit
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
Total		18
Total credits required:		194

AREA ELECTIVES

At least two of the three Area Electives must bear an ECE prefix at the 400 level or above
At most one of the Area Electives can bear an ECE or CSSE prefix at the 300 level or above
Exceptions to this requirement may be granted by the ECE Department Head

TECHNICAL ELECTIVE - Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering as a free elective or technical elective. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, geology or physics course as a math science elective except those courses that are cross-referenced with any engineering courses.

COMPUTER ENGINEERING CORE COURSES

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE312	Communication Networks	4
ECE332	Computer Architecture II	4
ECE343	High Speed Digital Design	4
ECE362	Principles of Design	3
ECE380	Discrete-Time Signals and Systems	4
or	or	
ECE320	Linear Control Systems	
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

SECOND MAJOR IN COMPUTER ENGINEERING

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.

Course Number	Course Title	Credits
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE312	Communication Networks	4
ECE332	Computer Architecture II	4
ECE343	High Speed Digital Design	4
ECE380	Discrete-Time Signals and Systems	4
or	or	
ECE320	Linear Control Systems	
CSSE120	Introduction to Software Development	4

CSSE220	Object-Oriented Software Development	4
CSSE232	Computer Architecture I	4
CSSE332	Operating Systems	4
or	or	
CSSE230	Data Structures & Algor Analysis	
MA381	Intro to Probability w/ Apps to Stats	4
Total		64

MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE160, ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Examples of Minors for Engineernig Physics and Optical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE180	Introduction to Signal Processing	4	ECE204	AC Circuits	4
ECE204	AC Circuits	4	ECE230	Introduction to Embedded Systems	4
ECE205	Circuits and Systems	4	ECE233	Introduction to Digital Systems	4
ECE300	Continuous-Time Signals Systems	4	ECE250	Electronic Device Modeling	4
ECE380	Discrete-Time Signals and Systems	4	ECE351	Analog Electronics	4
or	or				
ECE310	Communication Systems				

Examples of Minors for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Introduction to Signal Processing	4
ECE230	Introduction to Embedded Systems	4	ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4	ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4	ECE205	Circuits and Systems	4
ECE332	Computer Architecture II	4	ECE332	Computer Architecture II	4

Examples of Minors for Mechanical Engineering

Course	Course Title	Credits	Course	Course Title	Credits
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Number			Number		
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Introduction to Signal	4
ECE370	Power and Energy	4		Processing	
	Systems		ECE204	AC Circuits	4
ECE371	Sustainable Energy	4	ECE233	Introduction to Digital	4
	Systems			Systems	
ECE470	Power Systems I	4	ECE250	Electronic Device Modeling	4
ECE471	Industrial Power Systems	4	ECE351	Analog Electronics	4

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science

The Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The computer science curriculum is designed to prepare students for multiple careers in a rapidly changing environment. The department's courses emphasize fundamental concepts and techniques that will last longer than present technology.

Computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer architecture, programming languages, operating systems, and software engineering. Majors also complete important courses in closely related fields, e.g., discrete mathematics, digital logic design, and probability and statistics. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Courses in database systems, compilers, computer graphics, fractals and chaotic dynamical systems, artificial intelligence, theory of computation, analysis of algorithms, computer networks, computer vision, web-based information systems, and cryptography are available as advanced electives. A three-term senior project provides valuable practical experience in the specification, design, implementation, and documentation of large software systems. Qualified students can undertake independent study in advanced topics in computer science, participate in a research project with a faculty member, or complete a senior thesis.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

Computer science majors have diverse interests and career goals. Five free elective courses allow students to tailor their undergraduate education to their specific goals. Students planning to undertake graduate study in computer science usually take additional advanced courses in computer science, electrical engineering, and mathematics.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Computer science majors have unlimited access to the department's laboratories. Computer science majors are frequently employed by the computing center as user consultants, and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

Computer Science Program Educational Objectives

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Student Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering
13. Recognize the need for, and engage in, lifelong learning
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The computer science program is accredited by the Computing Accreditation Commission of ABET, www.abet.org

COMPUTER SCIENCE PLAN OF STUDY

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
Total		18
Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4
PH 112	Physics II	4
MA 112	Calculus II	5
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
Total		16
Winter Term		Credit
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
MA 375	Discrete & Combinatorial Algebra II	4

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Lang. Con.	4
ECE 332	Computer Architecture II	4
MA 381	Introduction to Probability with Applications to Statistics	4
RH 330	Technical and Professional Communication	4
Total		16

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 371	Software Requirements Engineering	4
CSSE/MA 473	Design and Analysis of Algorithms	4
CSSE	Elective	4
HSS	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
CSSE/MA 474	Theory of Computation	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE	Elective	4
	Technical Elective	4
Free	Elective	4
Free	Elective	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 487	Senior Research Project I or	4
CSSE 497	Senior Capstone Project I or	
CSSE 494	Senior Thesis I	
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 488	Senior Research Project II or	4
CSSE 498	Senior Capstone Project II or	
CSSE 495	Senior Thesis II	
CSSE	Elective	4
HSS	Elective	4
	Technical Elective	4
Total		14

<i>Spring Term</i>		<i>Credit</i>
CSSE 489	Senior Research Project III or	4
CSSE 499	Senior Capstone Project III or	
CSSE 496	Senior Thesis III	
Free	Elective	4
Free	Elective	4
Total		12
Total credits required:		192

CSSE electives cannot include any of CSSE 372, 373, 375, 376, and 477.
Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.
HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or

MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.

- 2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
- 3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
- 4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
- 5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
- 6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 7. A total of 192 credits.

Area Minor in Computer Science

Advisor: J.P. Mellor

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

CSSE120 Introduction to Software Development
CSSE220 Object-Oriented Software Development
CSSE230 Data Structures and Algorithm Analysis
16 additional credits of computer science courses numbered above 200.
None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories

2. use economic theory to define, analyze and solve a wide range of problems.

3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.

4. communicate complex economics topics in both oral and written form.

5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
or	or	
HSS	Elective	
SV 150	Intro to Microeconomics	4
or	or	
SV 152	Intro to Macroeconomics	
	Physical or Life Science	4
Total		18
Winter Term		Credit
MA 112	Calculus II	5
CSSE 120	Intro to Software Development	4
RH 131	Rhetoric and Composition	4
or	or	
SV 150	Intro to Microeconomics	
or	or	

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
	Economics Elective	4
	*HSS Elective	4
	Physical or Life Science	4
Total		16
Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Economics Elective	4
	*HSS Elective	4
	Physical or Life Science	4
Total		16
Spring Term		Credit
MA 381	Introd to Probability with Applications to Statistics	4
MA223	or	

Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

SV 152	Intro to Macroeconomics		Engineering Statistics	
	Physical or Life Science	4	Economics Elective	4
	Total	17	*HSS Elective	4
Spring		Credit	Physical or Life Science	4
Term			Total	16
MA 113	Calculus III	5		
RH 131	Rhetoric and Composition	4		
or	or			
SV 150	Intro to Microeconomics			
or	or			
SV 152	Intro to Macroeconomics			
	Physical or Life Science	4		
	*HSS Elective	4		
	Total	17		

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

- 1. 24 credits of required Economics courses:
SV150 Introduction to Microeconomics
SV152 Introduction to Macroeconomics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX456 Seminar for HSS Senior Projects
XX457 Directed Study for HSS Senior Project
- 2. 20 additional credits in Economics electives.
- 3. 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA211, 212 Differential Equations, and Matrix Algebra and Systems of Differential Equations
MA223 Engineering Statistics I or
MA381 Introduction to Probability
- 4. 12 additional credits in Mathematics other than MA351-356.
- 5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
- 6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
- 7. 4 credits in Engineering Management
- 8. 4 credits in Computer Science: CSSE 120
- 9. CLSK 100 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
TOTAL	192



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;

2. Function independently and in leadership positions within multidisciplinary teams;

3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;

4. Adapt and independently extend their learning to excel in fields about which they are passionate;

5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.

EE student outcomes

At the time of graduation, students will have demonstrated:

- an ability to apply knowledge of mathematics, science, and engineering

• an ability to design and conduct experiments, as well as to analyze and interpret data

• an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

• an ability to function on multidisciplinary teams

• an ability to identify, formulate, and solve engineering problems

• an understanding of professional and ethical responsibility

• an ability to communicate effectively

• the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

• a recognition of the need for, and an ability to engage in life-long learning

• a knowledge of contemporary issues

• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

ELECTRICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
PH 111	Physics I	4	MA 211	Differential Equations	4

- Biology

Biochemistry

Biomathematics

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Introduction to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
Total		17

Junior Year

Fall Term		Credit
ECE 380	Discrete-Time Signals and Systems	4
ECE 351	Analog Electronics	4
ECE 340	Electromagnetic Fields	4
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
ECE 320	Linear Control Systems	4
HSS	Elective	4
ECE 341	Electromagnetic Waves	4
	Math/Science Elective	4
Total		16

Spring Term		Credit
ECE 310	Communications Systems	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
Total		15

CHEM 111	General Chemistry	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
Total		16

Spring Term		Credit
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 370	Power & Energy Systems or	4
ECE 371	Sustainable Energy Systems	
ECE 250	Electronics Device Modeling	4
Total		16

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
	Math Elective	4
	Area Elective	4
HSS	Elective	4
Total		15

Winter Term		Credit
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
Total		16

Spring Term		Credit
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
Total		18
Total credits required:		194

AREA ELECTIVES

At least two of the three Area Electives must bear an ECE prefix at the 400 level or above
At most one of the Area Electives can bear an ECE or CSSE prefix at the 300 level or above
Exceptions to this requirement may be granted by the ECE Department Head

TECHNICAL ELECTIVE - Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering as a free electives or technical elective. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

ELECTRICAL ENGINEERING CORE COURSES

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Microcontrollers	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE 371	Power & Energy Systems or Sustainable Energy Systems	3
ECE380	Discrete-Time Signals and Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

SECOND MAJOR IN ELECTRICAL ENGINEERING

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Title	Credits
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits Systems	4
ECE230	Introduction to Microcontrollers	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE370	Power & Energy Systems	4
	or	

ECE371	Sustainable Energy Systems	
ECE380	Discrete-Time Signals and Systems	4
MA381	Introduction to Probability with Applications to Statistics	4
Total		64

AREA MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE160, ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Example Area Minor for Engineering Physics and Optical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE180	Intro to Signal Processing	4	ECE204	AC Circuits	4
ECE204	AC Circuits	4	ECE230	Intro to Embedded Systems	4
ECE205	Circuits and Systems	4	ECE233	Intro to Digital Systems	4
ECE300	Continuous Time Signals and Systems	4	ECE250	Electronic Device Modeling	4
ECE380	Discrete-Time Signals and Systems	4	ECE351	Analog Electronics	4
or					
ECE310	or Communication Systems				

Examples Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Intro to Signal Processing	4
ECE230	Intro to Embedded Systems	4	ECE205	Circuits and Systems	4
ECE233	Intro to Digital Systems	4	ECE230	Intro to Embedded Systems	4
ECE250	Electronic Device Modeling	4	ECE233	Intro to Digital Systems	4
ECE332	Computer Architecture II	4	ECE332	Computer Architecture II	4

Examples Area Minor for Mechanical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Intro to Signal Processing	4
Required			ECE204	AC Circuits	4
ECE370	Power & Energy Systems	4	ECE233	Intro to Digital Systems	4
ECE371	Sustainable Energy	4	ECE250	Electronic Device Modeling	4

	Systems		ECE351	Analog Electronics	4
ECE470	Power Systems I	4			
ECE471	Industrial Power Systems	4			

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

ENHANCED STUDY IN COMMUNICATION SYSTEMS

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 312 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Continuous-Time Signals Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Circuits and Systems
- ECE300 Continuous-Time Signals Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

ENHANCED STUDY IN POWER SYSTEMS

Power Certificate

Take all of the following courses:

- ECE 473 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

ECE 310 Communication Systems
OE 393 Fiber Optics and Applications
OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 312 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

EP Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will contribute to society locally, nationally or globally
- Our graduates will collaborate within their organization; and be active in research and development in a relevant area of science and technology.
- Our graduates will continue to develop professionally.

EP Student Learning Outcomes

- Outcome A:

Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
- Outcome B1:

Interpreting Data: Ability to interpret graphical, numerical, and textual data.
- Outcome B2:

System Level Modeling: Ability to model components and system level engineering problems.
- Outcome B3:

Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

Outcome C:	Design: Ability to design a product or process to satisfy client's needs subject to constraints.
Outcome D:	Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
Outcome E:	Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
Outcome F:	Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
Outcome G:	Communication: Ability to communicate effectively in oral, written and visual forms.
Outcome H:	Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
Outcome I:	Life Long Learning: A facility for independent learning and continued professional development.

The engineering physics program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

ENGINEERING PHYSICS (Micro-Nano)

Freshman Year

Fall Term		Credit
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graphical Communications	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
OE 172	Optics in Technology*	2
EM 103	Introduction to Design**	2
Total		17*

Junior Year

Fall Term		Credit
PH 316	Electric and Magnetic Fields	4
ENG	200 Level Engineering Elective	4
PH 405	Semiconductor Materials and Applications	4
MA 223	Engineering Statistics I	4
Total		16

Sophomore Year

Fall Term		Credit
ECE 203	DC Circuits	4
PH 235	Many Particle Physics	4
MA 211	Differential Equations	4
SEM	Sci, Engr or Math Elective	4
Total		16

Winter Term		Credit
EP 280	Intro to Nano Engineering	4
PH 255	Foundations of Modern Physics	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 204	AC Circuits	4
Total		16

Spring Term		Credit
EP 380	Nano Technology Entrepreneurship and Ethics	4
OE 295	Optical Systems	4
SV 151	Principles of Economics	4
EM 121	Statics	4
Total		16

Senior Year

Fall Term		Credit
EP 416	Engineering Physics Project II	4
EP 407	Semiconductor Fabrication and Characterization	4
EP 411	Advanced MEMS	4
HSS	Elective	4
Total		16

Winter Term		Credit
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Winter Term		Credit
HSS	Elective	4
PH 317	Electromagnetism	4
RH 330	Technical and Professional Communication.	4
EP 406	Semiconductor Devices and Fabrication	4
Total		16

Spring Term		Credit
PH 327	Thermodynamics & Stat Mech	4
EP 410	Intro to MEMS	4
EP 415	Engineering Physics Project I	4
HSS	Elective	4
Total		16

EP 417	Engineering Physics Project III	4
ENG	300/400 Engineering Elective	4
HSS	Elective	4
PH 401	Intro Quantum Mechanics	4
Total		16

Spring Term		Credit
HSS	Elective	4
HSS	Elective	4
ENG	Engineering Elective	4
Free	Free Elective	4
Total		16
Total credits required:		194

***If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.**

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

Subjects	#Classes	Hours
Physics(PH)	10	40
Math(MA)	6	27
Chemistry(CHEM)	2	8
ME	1	4
EM	3	8
CLSK	1	1
Electrical Engineering	2	8
Optical Engineering (OE)	2	6
HSS	9	36
Engineering Physics (EP)	6	24
Engineering Physics Project(EP)	3	12
Elective(SEM, Eng. and Free)	5	20
Total	50	194

SUMMARY OF GRADUATION REQUIREMENTS FOR ENGINEERING PHYSICS

1. All the courses listed above by the number.
2. The program must be approved by the EP advisor.
3. A list of the engineering electives is provided.
4. SEM (Science, Engineering, Math) electives are courses that need to be taken at the 200 level (CHEM115 is allowed) or above in the physics, chemistry, math, or biology programs.
5. A free electives is any course in engineering, science, humanities, military science, or air science.

Classes by Subjects	Hours
Physics Coursework*	40
Chemistry and Mathematics Coursework**	35
Humanities and Social Science(Standard requirement)	36
EM, ME, CLSK Courses	13
Electrical Engineering Courses	8
Optical Engineering Courses	6
EP Courses	24
EP Projects	12
Engineering Electives	8
SEM and Free Electives	8

Total	193
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Foundation Physics Classes

Course	Description	Hours
PH 235	Many Particle Physics	4
PH 255	Modern Physics	4
PH 316	Electric & Magnetic Fields	4
PH 317	Electromagnetism	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Introduction to Quantum Mechanics	4
Total		24

General Foundation Classes

Course	Description	Hours
PH 111	Physics I	4
PH 112	Physics II	4
PH 113	Physics III	4
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 223	Engineering Statistics	4
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
Total		47

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	2
OE 172	Lasers and Fiber Optics	2
EM 121	Statics I	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
EP 280	Introduction to Nano-engineering	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
OE 295	Photonic Devices and Systems	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
EP 411	Advance Topics in MEMS	4
EP 407	Semiconductor Fabrication % Characterization	4
	Engineering Elective	12
ME123	Computer Applications	4
Total		68

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	4
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Approved Engineering 200-Level Electives (4 credit hours required)

- ECE 205 Circuits and Systems
- ES 201 Conservation and Accounting Principles

- ES 202 Fluid and Thermal Systems
- EM 204 Statics II
- OE 280 Geometric Optics
- EP 290 Directed Study
- EP 490 Directed Study

Approved Engineering Electives

- OE 360 Optical Materials
- OE 393 Fiber Optics
- OE 437 Introduction to Image Processing
- OE 450 Laser Systems and Applications
- OE 495 Optical Metrology
- EP 330 Materials Failure
- EP 470 Special Topics in Engineering Physics
- EP 490 Directed Study
- CHE 315 Materials Science and Engineering
- ME 328 Materials Engineering
- ME 417 Advanced materials Engineering
- ME 422 Finite Elements for Engineering Applications
- EM 403 Advanced Mechanics of Materials
- ECE 351 Analog Electronics
- ECE 250 Electronic Device Modeling



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computing industry and prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman international computer science graduates to be:

- 1. Graduate students and researchers.
- 2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
- 3. Entrepreneurial leaders.
- 4. Business and technological leaders within existing organizations.
- 5. Actively involved in social and professional service locally, nationally, and globally.
- 6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
- 7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

International Computer Science Student Outcomes

By the time students graduate with an international computer science degree from Rose-Hulman, they will be able to:

- 1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools.
- 2. Anticipate complexities and problems involved in the development of large software systems.
- 3. Analyze requirements, design software that satisfies those requirements, and implement that software.
- 4. Analyze problems using ideas of problem complexity, models of computation, and decidability.
- 5. Design algorithms using a variety of paradigms.
- 6. Analyze algorithms in terms of correctness as well as time and space efficiency.
- 7. Communicate effectively, both verbally and in writing.
- 8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry.
- 9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering.
- 10. Collaborate effectively in small teams.
- 11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering.
- 12. Explain the impact of globalization on computing and software engineering.
- 13. Recognize the need for, and engage in, lifelong learning.
- 14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4
MA 112	Calculus II	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
GE 111	German Language and Culture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete and Combinatorial Algebra I	4
Total		16

Winter Term		Credit
CSSE 230	Data Structures and Algorithm Analysis	4
GE 112	German Language and Culture II	4
MA 375	Discrete and Combinatorial Algebra II	4

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

Tech	Elective	4
Total		16
<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Language Concepts	4
GE 113	German Language and Culture III	4
MA 381	Introduction to Probability with Statistical Applications	4
RH 330	Technical and Professional Communication	4
Total		16

Junior Year (at Hochschule Ulm, Germany)

<i>First Semester</i>		<i>Credit</i>
VSYS (CSSE443)	Distributed Systems & IT Security	4
ECHT (CSSE444)	Real-time Systems	4
IPRO (CSSE371)	Project Management & Integrated Project I	4
SEM (CSSE400)	Seminar	4
	Technical German	4
Free	Elective	4
Total		24

<i>Second Semester</i>		<i>Credit</i>
COMPA (CSSE232)	Computer Architecture	4
BSYS (CSSE332)	Operating Systems	4
DABA (CSSE333)	Databases	4
IPRO (CSSE374)	Project Management & Integrated Project II	4
RNET (CSSE432)	Computer Networks	4
	Humanities Course	4
Total		24

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 494	Senior Thesis I	4
ECE 332	Computer Architecture II	4
Free	Elective	4
Free	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 495	Senior Thesis II	4
CSSE/MA 474	Theory of Computation	4
Tech	Elective	4
Free	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 496	Senior Thesis III	4
CSSE/MA 473	Design and Analysis of Algorithms	4
Free	Elective	4
Total		12
Total Credits Required		192

Summary of graduation requirements for the international computer science major

HSS electives must be distributed as required by HSS. Science elective is any CHEM, PH, GEOL, or BIO course(s) totaling at least 4 credits.

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number, symbol, or name in the schedule of courses above: CSSE 120, CSSE 132, CSSE 220, CSSE 230, CSSE 304, CSSE or MA 473, CSSE or MA 474, and CSSE 494-6; MA 111, MA 112, MA 113, MA 212, MA 275, MA 375, MA 381; ECE 332; PH 111, PH 112; CHEM 111; RH 131, RH 330; GE 111, GE 112, GE 113; CLSK 100; BSYS, COMPA, DABA, ECHT, IPRO, RNET, SEM,

VSYS, Technical German.

- 2. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the international computer science major.
- 3. Eight additional credits of technical electives. Consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
- 4. Twelve credits of additional courses offered by the Department of Humanities and Social Sciences and/or appropriate humanities or social science courses offered at Hochschule Ulm. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences at Rose-Hulman.
- 5. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 6. A total of 192 credits.



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CATALOG HOME

Mathematics

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of

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|---------------------------------------|
| Biology |
| Biochemistry |
| Biomathematics |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| International Computer Science |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

DEGREE REQUIREMENTS

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core	12 hrs.
Three courses selected per the list below. Students completing the Continuous Applied	

Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry, mathematics modeling or application, or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- MA 493 and MA 494 must be taken in seperate terms.
- The requirement of MA 491-492 may be fulfilled through some project experience (such as an internship) and another 300-level or above mathematics course (4 hours), as approved by the project advisor. The course substitution procedure must be used.
- The project must involve work done by the student(s) to solve a problem presented by

an external sponsor or a problem with a substantial mathematical modeling, application and/or computational content. The written project submission must be approved by the advisor and/or sponsor, and must be presented publicly to the department.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team).
- The approved written thesis must be submitted to the department for archiving and must be publicly presented to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.

Total hours required for graduation	195 hrs.
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* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
BIO 101 — Essential Biology (or higher-level BIO course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	
*** 200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.	24 hrs.
**** CLSK 100 — College and Life Skills	1 hr.
MA 200 - Career Preparation (primary major only)	1 hr.

SUGGESTED SCHEDULE

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math

elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended science schedule of six science courses starts with PH 111. If CHEM 111 is required in the fall quarter because of a double major or minor, then the alternate science sequence may be completed by taking the second science course in each place where a choice is given. Two science courses are to be taken in the winter quarter of freshman year.

MATHEMATICS

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
	or	
CHEM 111	General Chemistry I	4
RH 131	Rhetoric and Composition	
	or	4
HSS	Elective	
CLSK 100	College and Life Skills	1
CSSE 120	Introduction to Software Development	4
Total		18

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
	or	
PH 111	Physics I	4
CHEM 111	General Chemistry I	
	or	4
BIO 101	Essential Biology (or higher level BIO course)	
HSS	Elective	4
	or	
RH 131	Rhetoric Composition	17
Total		

Spring Term		Credit
MA 113	Calculus III	5
PH 113	Physics III	4
	or	
PH 112	Physics II	2
MA 190	Contemporary Mathematics Problems	
HSS	Elective	4
Total		15

Junior Year

Fall Term		Credit
MA	Elective	4
	Technical Elective	4
	Technical Elective	4
HSS	Elective	4
	or	
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
MA 366	Functions of a Real Variable	4

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
MA 275	Disc. & Comb. Algebra I	4
BIO 101	Essential Biology (or higher level BIO course)	4
	or	
PH 113	Physics III	4
*CSSE 220	Object-Oriented Software Development	
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Science Elective	4
	Technical Elective	4
HSS	Elective	1
**MA 200	Career Preparation	
Total		17

Spring Term		Credit
MA 381	Introduction to Probability	4
MA 371	Linear Algebra I	4
	Technical Elective	4
HSS	Elective	4
Total		16

Senior Year

Fall Term		Credit
MA 491	Intro to Math Modeling (2 hours)	4
MA 492	Senior Project I (2 hrs.)	4
	or	
MA 496	Senior Thesis I (4 hrs.)	4
	Free Elective	
	Free Elective	4
HSS	HSS	
Total		16

Winter Term		Credit
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MA	Elective	4
	Technical Elective	
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
Total		16

Spring Term		Credit
MA	Elective	4
MA	Elective	4
	Technical Elective	4
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
Total		16

MA 493	Senior Project II (2 hrs.)	
	or	2
MA 497	Senior Thesis II (2 hrs.)	
MA	Elective	4
	Free Elective	4
	Free Elective	4
	Free Elective	4
Total		18

Spring Term		Credit
MA 494	Senior Project III (2 hrs.)	
	or	2
MA 498	Senior Thesis III (2 hrs.)	
MA	Elective	4
	Free Elective	4
	Free Elective	4
Total		14

Total credits required: 195

Notes:

- *MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework
- **MA 200 - Career Preparation - may be taken in the winter quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- **Math Elective:** A course either required by the concentration or a true math elective.
- **Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- **Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- **Free Elective:** Any course.

Computational Science Major (CPLS) (Second Major Only)

Computational methods are widely employed in science and engineering for simulation, experimentation, analysis, and design. In many areas the use of high-performance computing is essential. The Computational Science major provides Rose-Hulman students with the opportunity to add to their primary major a second major that increases their knowledge and skill in applied scientific and engineering computation.

Requirements for a second major in Computational Science (71 credit hours)

The second major in Computational Science is open to all students. It requires 71 credit hours, including a 55 credit hour core and a 16 credit hour specialization. The courses used to satisfy the requirements in the Advanced Core may not be counted toward any other major or minor. All Computational Science programs of study are subject to approval by the Chair of the Computational Science Steering Committee

I. Computational Science Core (55 credit hours)

Fundamentals (35 credit hours)

- MA 111, 112, 113 Calculus I, II, III
- MA 211 Differential Equations
- MA 212 Matrix Algebra and Systems of Differential Equations
- CSSE 120 (1) Introduction to Software Development, or any of BE 100, CE 110, CHE 110 (plus 2

cr.), ME 123

- CSSE 132, ECE233, or ME430 - Introduction to Computer Systems, Introduction to Digital Systems, or Mechatronic Systems
- MA 332 (2) Introduction to Computational Science, or any of CE 310 (plus 2 cr.) CHE 310, ME 323 (plus 2 Credits)

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any upper-level computational science course (see list below)

List of Advanced Electives

- BE 510 Biomedical Signal and Image Processing
- CHE 521 Advanced Chemical Engineering Computation
- CSSE 304 Programming Language Concepts
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- ECE 582/PH 537 Advanced Image Processing
- EMGT 526 Technology Forecasting
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 348 Continuous Optimization
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis
- MA 435 Finite Difference Methods
- MA 439 Mathematical Methods of Image Processing
- MA 444 Deterministic Models in Operations Research
- MA 446 Combinatorial Optimization
- MA 490 Mathematical Biology
- ME 422 Finite Element Methods for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Elements Analysis
- Other courses may be counted as advanced electives upon approval by the Chair of Computational Science.

II. Area of Concentration (16 credit hours): Each student must complete 16 credit hours in an area of concentration within Computational Science. Courses used to satisfy the core requirements may not be used to satisfy the area of concentration requirements.

Computational Methods

- MA 371 or MA 373 Linear Algebra I, Applied Linear Algebra for Engineers
- MA 433 Numerical Analysis
- Eight credit hours chosen from CSSE 304, CSSE/MA 473, MA 348, MA 386, MA 434, MA 435, MA439, MA 444, MA 446, MA 485, ME 422

Computational Mechanics

- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- ME 401 Foundations of Fluid Mechanics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Element Analysis

Computational Signals and Image Processing

- ECE 380 Discrete-Time Signals and Systems
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- MA 439 Mathematical Methods of Image Processing

Computational Physics and Chemistry

- CHEM 361 Physical Chemistry I
- CHEM 362 Physical Chemistry II
- CHEM 363 Quantum Chemistry & Molecular Spectroscopy
- OE 570 Nanomedicine
- PH 540 Computer Physics

Computational Biomedics

- BE 482/MA 482 Bioengineering Statistics
- BE 535/OE 535 Biomedical Optics
- BE 541/ECE 597 Medical Imaging
- MA 490-01 Mathematical Biology 1
- MA 490-02 Mathematical Biology 2

AREA MINOR IN MATHEMATICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

AREA MINOR IN COMPUTATIONAL SCIENCE

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research

- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the major.
- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

AREA MINOR IN STATISTICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- **Globally required mathematics courses**
MA 111 Calculus I
MA 112 Calculus II
MA 113 Calculus III
MA 212 Differential Equations
- **Required Introductory Statistics/Probability Courses**
MA 381 Introduction to Probability with Applications to Statistics,
One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is taken before MA223/MA382 the student will be strongly recommended to take MA382.
- **Required Second Statistics Course**
One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics
- **Electives**
3 courses (12 credits) selected from the following list, at least two of which must be starred. Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.

MA 385* Quality Methods
MA 386* Statistical Programming
MA 387* Statistical Methods in Six Sigma
MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers
MA 445 Stochastic Models in Operations Research
MA 481* Mathematical Statistics
MA 485* Regression and Time Series Analysis
MA 487* Design of Experiments
MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students
- Only MA111, MA112, MA113, MA212 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.



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Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

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Mechanical Engineering

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Design Processes and Methodology.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 20 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

Vision: To graduate the best baccalaureate mechanical engineers.

- | |
|---------------------------------------|
| Biology |
| Biochemistry |
| Biomathematics |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| International Computer Science |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- | |
|---|
| Air Force ROTC (Military) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS) (Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Army ROTC (Military) |
| Pre-Professional Programs |

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

- a. *an ability to apply knowledge of mathematics, science, and engineering*
- b. *an ability to design and conduct experiments, as well as to analyze and interpret data*
- c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
- d. *an ability to function on multi-disciplinary teams*
- e. *an ability to identify, formulate, and solve engineering problems*
- f. *an understanding of professional and ethical responsibility*
- g. *an ability to communicate effectively*
- h. *the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
- i. *a recognition of the need for, and an ability to engage in life-long learning*
- j. *a knowledge of contemporary issues*
- k. *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*

Area Minor*** in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

ME 301 Thermodynamics II
CHE 303 Chem. Engineering Thermodynamics
ME 302 Heat Transfer
CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems

- ME 407 Power Plants**
- ME 408 Renewable Energy
- ME 409 Air Conditioning*
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems**
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundation of Fluid Mechanics
- ME 402 Advanced Heat Transfer*
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 450 Combustion
- ME 501 Advanced Thermodynamics**
- ME 502 Topics in Heat Transfer*
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

**Requires one of the thermodynamics prerequisites from section 2 above.
* Requires one of the heat transfer prerequisites from section 2 above.
*** ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may include special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

- ECE/ME 497 Introduction to Model-Based System Design
- ECE/ME 497 Advanced Model Based-System Design

Elective Courses

- CHEM 470 Combustion Chemistry

- ECE 320 Linear Control Systems
or
ME 406 Control Systems

- ECE 420 Nonlinear Control Systems
or
ME 506 Advanced Control Systems

- ECE 370 Machines & Power
- ECE 410 Communication Networks
- ECE 452 Power Electronics

- ME 408 Renewable Energy
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 422 Finite Elements for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 450 Combustion

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

- MA 336 Boundary Value Problems*
- ME 405 Theoretical Aerodynamics*
- ME 401 Foundation of Fluid Mechanics*
- ME 411 Propulsion Systems*
- ME 422 Intro to Finite Element Fundamentals*
- ME 426 Turbomachinery*
- ME 427 Introduction to Computational Fluid Dynamics*
- ME 461 Aerospace Design*
- ME 503 Viscous Flow*
- ME 510 Gas Dynamics*
- ME 512 Light Weight Structures*
- ME 522 Advanced Finite Element Analysis*
- PH 322 Celestial Mechanics*

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 or CHE 450 Air Pollution (cross-listed class)*
- CE 590 Climate Change Assessment*
- CHE 490 Energy and Environment*
- CHE 512 Petrochemical Processes*
- ECE 370 Power and Energy Systems*
- ECE 371 Industrial Power Systems*
- ME 407 Power Plants*
- ME 408 Renewable Energy*

ME 450 Combustion
ME 501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

MA 385 Quality Methods
MA 487 Design of Experiments
MA 387 Statistical Methods in Six Sigma

Engineering Management List

EMGT 330 Introduction to Engineering Management
EMGT 427 Project Management
EMGT 520 Accounting for Technical Managers
EMGT 521 Financial Management in a Technical Environment
EMGT 522 Organizational Management
EMGT 523 Marketing Issues in a Technical Environment 4
EMGT 524 Production/Operations Management
EMGT 526 Technology Management and Forecasting
EMGT 527 Project Management
EMGT 531 Economics for Technical Managers
EMGT 532 Technical Entrepreneurship
EMGT 533 Intercultural Communication
EMGT 534 Management Science
EMGT 535 Strategies for Organizational Change
EMGT 586 Supply Chain Management
EMGT 587 Systems Engineering
EMGT 588 Quality Management I
EMGT 589 Manufacturing Systems

Humanities, Social Sciences List

GS 350 International Trade
GS 351 International Finance
IA 230 Fundamentals of Public Speaking
SV 151 Principles of Economics
SV 350 Managerial Accounting
SV 351 Managerial Economics
IA 352 Game Theory
SV 303 Business and Engineering Ethics
SV 304 Bioethics
SV 352 Money & Banking
SV 353 Industrial Organization
SV 354 Environmental Economics
SV 356 Corporate Finance
EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 588 Quality Management
- EMGT 589 Manufacturing Systems
- MA 385 Quality Methods
- ME 317 Design for Manufacturing
- ME 417 Advanced Materials Engineering
- ME 435 Robotics
- ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 450 Combustion
- ME 501 Advanced Thermodynamics
- ME 502 Topics in Heat Transfer
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the **Thermal Fluid Systems**list and at least two courses are taken from the **Thermal Fluid Sciences**list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET,www.abet.org

MECHANICAL ENIGNEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
RH 131	Rhetoric and Composition split fall or winter with Elective	4
HSS		
Total		16
Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
EM 121	Statics and Mechanics of Materials I	4
RH 131	Rhetoric and Composition split fall or winter with Elective	4
HSS		
Total		17
Spring Term		Credit
MA 113	Calculus III	5
PH 113	Physics III	4
EM 103	Introduction to Design	2
ME 123	Computer Applications I	4
Total		15

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
ES 201	Conservation & Accounting Principles	4
ES 203	Electrical Systems	4
HSS	Elective	4
Total		16
Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ES 202	Fluid & Thermal Systems	3
ES 204	Mechanical Systems	3
CHEM 111	General Chemistry I	4
HSS	Elective	4
Total		18
Spring Term		Credit
MA 223	Statistics for Engineers	4
ES 205	Analysis & Design of Engineering Systems	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		16

Junior Year

Fall Term		Credit
ME 301	Thermodynamics II	4
EM 204	Statics & Mechanics of Materials	4
ME406	Control Systems	4
or	or	
EM 406	Vibration Analysis	
*Free	Elective	4
Total		16

Winter Term		Credit
ME 317	Design for Manufacturing	3
ME 321	Measurement Systems	4
	split winter or spring with	
ME 323	Computer Applications II	(2)
MA/Science	Math or Science Elective	4
ME 328	Materials Engineering	4
RH 330	Technical Communications	4
	split winter or spring with	
HSS	Elective	
Total		(17)
		or 15

Spring Term		Credit
ME 302	Heat Transfer	4
ME 323	Computer Applications II	2
MA/Science	Math or Science Elective	4
	split winter or spring with	
ME 321	Measurement Systems	
ME 470	Engineering Design Proc & Method	3
	split Jr. spring or Sr. fall with	(4)
ME 480	Machine Component Design	
HSS	Elective	4
	split winter or spring with	
RH 330	Technical Communications	
Total		(16)
		or 17

Senior Year


Fall Term		Credit
ME 430	Mechatronic Systems	4
	split fall or winter with	
ME 421	M.E. Lab and *Tech Elective	(2+4)
*Tech	Elective	4
ME 480	Machine Component Design	4
	split Jr. spring or Sr. fall with	
ME 470	Engineering Design Proc & Method	(3)
*Tech	Elective	4
Total		(17)
		or 16

Winter Term		Credit
ME 471	Capstone Design I	(3) 3
ME 421	M.E. Lab and *Tech Elective	2+4
	split fall or winter with	
ME 430	Mechatronic Systems	(4)
HSS	Elective	4
*Free	Elective	4
Total		(15)
		or 17

Spring Term		Credit
ME 472	Capstone Design II	3
*Tech	Elective	4
*Tech	Elective	4
HSS	Elective	4
Total		15
Total credits required:		194

*28 credit hours. in electives composed of 20 cr. hrs. in technical electives and 8 cr. hrs. in free electives.

*A **technical elective** is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A **science elective** is any course in biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.

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Programs of Study

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>

OE Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will make a meaningful impact on society.
- Our graduates will behave ethically and act as responsible members of the engineering and science community.
- Our graduates will continue to develop professionally

OE Student Learning Outcomes

Outcome A: An ability to apply knowledge of mathematics, science, and engineering

Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

- Demonstrate competency in applying knowledge of mathematics (such as multivariable calculus, differential equations, linear algebra, complex variables, and probability and statistics), physics and chemistry
- Demonstrate competency in applying basic engineering science topics with common themes among engineering disciplines
- Demonstrate competency in applying theoretical and experimental knowledge in geometrical optics, physical optics, optical materials and devices to modeling, analysis and design of optical/photonic devices and systems

Outcome B:

An ability to design and conduct experiments, as well as to analyze and interpret data

- Identify the problem and determine what data need to be collected.
- Apply safe laboratory practices
- Select appropriate measurement techniques to collect the data.
- Demonstrate the ability to use laboratory equipment for measurement.
- Use appropriate statistical and analytical procedures to estimate uncertainties and interpret results
- Be able to recognize the necessity to use graphical and numerical analysis
- Extract trends and demonstrate their importance from numerical data, graphs, and text.
- Draw conclusions

Outcome C:

An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

- Elicit customer needs and define realistic constraints
- Identify viable alternatives in design and make an informed selection.
- Break down a system/process to its fundamental elements and components.
- Carry out design using appropriate tools.
- Incorporate economic analysis and analyze cost in design.
- Apply appropriate engineering standards.
- Deliver a functional prototype that meets customer needs.
- Document project work and give an oral and formal written report.

Outcome D:

An ability to function on multidisciplinary teams

- Share responsibilities and team duties by taking on different roles when applicable.
- Set milestones for the project.
- Discern feasible solutions.
- Develop a strategy for action.
- Meet objectives on schedule.
- Document work.
- Build consensus.

Outcome E:

An ability to identify, formulate, and solve engineering problems

- Identify, inspect, and define problems.
- Understand the basic principles and fundamental concepts required to solve problems
- Research and gather information.
- Use correct data, tools and adequate assumptions to solve problems.
- Demonstrate an awareness of multiple possible solutions.
- Develop criteria for evaluation of solutions.

Outcome F:

An understanding of professional and ethical responsibility

- Demonstrate knowledge of the Code of Ethics for Optical Engineers
- Evaluate the ethical dimensions of professional practice.
- Practice responsible decision making.

Outcome G:

An ability to communicate effectively

- Identify the technical knowledge and information needs of the audience.
- Provide technical content that is factually correct, supported with evidence, explained with sufficient detail, and properly documented.
- Summarize the graphical, numerical, and textual information in memos and reports.
- Submit work that is free of errors in spelling, punctuation, grammar, and usage.

Outcome H: The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

- Show an awareness of the impact of technology on culture and the environment and vice versa.

Outcome I: A recognition of the need for, and an ability to engage in life-long learning

- Demonstrate the ability to independently find and use technical information
- Demonstrate awareness of the current trend of optics/photonics technology by participating in exchange programs, internships, presentations or professional society activities.

Outcome J: A knowledge of contemporary issues

- Be knowledgeable of contemporary issues related to engineering practice

Outcome K: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- Design, construct, and align optical systems using light sources, optical components, mounts, and detection systems
- Use basic programming (e.g. Matlab or C+) for engineering practice.
- Use appropriate software tools for modeling optical devices and systems (e.g. Code V, Zemax, Light Tools)
- Use appropriate software tools for data analysis and presentation

The optical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

OPTICAL ENGINEERING

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graph Comm	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
OE 172	Lasers and Fiber Optics *	2
EM 103	Intro Eng. Design	2
Total		17

Sophomore Year

Fall Term		Credit
PH 235	Many-Part Physics	4
PH 292	Physical Optics	4
MA 211	Differential Equations	4
ECE 203	DC Circuits	4
Total		16

Winter Term		Credit
ECE 204	AC Circuits	4
PH 255	Fnd. of Mod. Phys.	4
MA 212	Matrix Algebra & Sys of Diff Equat	4
OE 280	Geometrical Optics	4
Total		16

Spring Term		Credit
OE 295	Photonic Devices & Systems	4
SV 151	Principles of Economics	4
MA 223	Engineering Statistics	4
Free Elective		4
Total		16

Junior Year

Fall Term		Credit
OE 392	Linear Optical Systems	4
OE 395	Opto-Mech & Optical Eng Lab	4
PH 316	Elec & Mag Fields	4
HSS	Elective	4
Total		16

Winter Term		Credit
OE 393 or OE 360	Fiber Optics & Applications or Optical Materials	4
RH 330	Tech & Prof Communications	4
HSS	Elective	4
	Free Elective	4
Total		16

Spring Term		Credit
OE 415	Opt Eng Des I	4
OE 450	Laser Systems & Applications	4
HSS	Elective	4
	Engineering Elective**	4
Total		16

Senior Year

Fall Term		Credit
OE 416	Optical Eng Design II	4
OE 480	Optical System Design	4
PH 405	Semiconductor Materials & Appl	4
HSS	Elective	4
Total		16

Winter Term		Credit
OE 417	Optical Engineering Design III	4
OE 495	Optical Metrology	4
OE 393 or OE 360	Fiber Optics and Applications or Optical Materials	4
PH/OE/EP	Elective ***	4
Total		16

Spring Term		Credit
HSS	Elective	4
HSS	Elective	4
	Engineering Elective**	4
	Free Elective	4
Total		16

Total credits required: 194

*If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

**An engineering elective is any 200, 300, or 400-level course listed as OE, EP, ECE, ME, CE, BE, EM or ES.

***A PH/OE/EP elective is any 200, 300, or 400-level course listed as OE, EP or PH.

SUMMARY OF GRADUATION REQUIREMENTS FOR OPTICAL ENGINEERING

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects	Hours
Optics Coursework	46
Physics Coursework	20
Freshmen Physics, Chemistry and Mathematics Coursework	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous	25
Total	194

Physics Classes		
Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4

PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM111	Engineering Chemistry I	4
CHEM113	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
Total		17

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Leisher, Siahmakoun, and Wagner.

Required Courses (12 hours)

Course	Hours	Course Description
OE 280	4	Geometrical Optics
PH 292	4	Physical Optics
OE 295	4	Photonic Devices and Systems

Plus at least two courses (8 hours) from the list below:

Course	Hours	Course Description
OE 360	4	Optical Materials
OE 392	4	Linear Optical Systems
OE 393	4	Fiber Optics and Applications
OE 395	4	Optomechanics & Optial Engineering Lab
OE 434	4	Non-Imaging Optics
OE 435	4	Biomedical Optics
OE 437	4	Introduction to Image Processing
OE 450	4	Laser Systems and Applications
OE 470	4	Special Topics in Optical Engineering
OE 480	4	Optical System Design
OE 493	4	Fundamentals of Optical Fiber Communications
OE 495	4	Optical Metrology

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)

Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203	4	DC Circuits
ECE 204	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as

optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

- 1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
- 2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

PHYSICS

Freshman Year		
Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
RH 131 or HSS	Rhetoric and Comp or HSS Elective	4
EM 104	Graphical Communications	2
Total		16

Winter Term		
		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 111	General Chemistry I	4
	Computing Elective*	2-4
Total		15 or 17

Spring Term		
		Credit

Sophomore Year		
Fall Term		Credit
	Free Elective†	4
PH 235	Many Particle Physics	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
PH 292	Physical Optics	4
Total		16

Winter Term		
		Credit
PH 255	Fund. of Modern Physics	4
HSS	Elective	4
	Technical Elective	4
MA 211	Differential Equations	4
Total		16

Spring Term		
		Credit
PH 314	Theoretical Mechanics I	4

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

PH 113	Physics III	4
MA 113	Calculus III	5
CHEM 113	General Chemistry II	4
HSS or RH131	HSS Elective or Rhetoric and Composition	4
Total		17

Junior Year

Fall Term		Credit
HSS	Elective	4
PH 316	Electric and Magnetic Fields	4
	Technical Elective†	4
PH 405	Semiconductor Materials and Applications	4
Total		16

Winter Term		Credit
PH 317	Electromagnetism	4
PH 401	Intro Quantum Mechanics	4
HSS	Elective	4
	Physics Elective†	4
Total		16

Spring Term		Credit
PH 325	Advanced Physics Lab I	4
HSS	Elective	4
OE 450	Laser Sys & App or Physics Elective†	4
PH 327	Thermodynamics & Statistical Mechanics	4
Total		16

HSS	Elective	4
MA 371 -or- MA 373	Linear Algebra I -or- Applied Linear Algebra for Engr	4
	Math Elective†	4
Total		16

Senior Year

Fall Term		Credit
Math	Elective†	4
	Technical Elective†	4
HSS	Elective	4
	Free Elective	4
Total		16

Winter Term		Credit
PH 425	Advanced Physics Lab II	4
HSS	Elective	4
	Technical Elective†	4
	Free Elective†	4
Total		16

Spring Term		Credit
	Technical Elective†	4
OE 450	Laser Sys & App or Physics Elective	4
	Free Elective	4
	Physics Elective†	4
Total		16

Total credits required: 192

* Computing elective: 2 or 4 credit course on computing from the following course: BIO 100, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

SUMMARY OF GRADUATION REQUIREMENTS FOR PHYSICS MAJORS

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
6. Sixteen credits of free electives (cannot include ECE340).
7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
8. A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.

9. A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
PH 215	Introduction to Chaos	2
PH 231	Intro to Astronomy and Astrophysics	4
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 322	Celestial Mechanics and Solar	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
PH 407	Solid State Physics	4
PH 410	General Relativity	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	Arranged
PH 470	Directed Research	Arranged
PH 480	Seminar	Arranged
PH 490	Directed Research	Arranged
PH 497+	Senior Thesis	Arranged
PH 498+	Senior Thesis	Arranged
PH 499+	Senior Thesis	Arranged
PH 512	Methods of Mathematical Physics	4
PH 514	Quantum Mechanics	4
PH 530	Advanced Acoustics	4
PH 537	Advanced Image Processing	4
PH 538	Introduction to Neural Networks	4

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year for a total number of 8 credit hours over the three quarter sequence. Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

**Math and Chemistry Courses:

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Linear Algebra	

MA 371	General Chemistry I	4
CHEM 111	General Chemistry II	4
CHEM 113		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus 12 credit hours from the following courses:

Course	Course Title	Hours
PH 270/470	Special Topics in Physics †	ARR
PH 290/490	Directed Research †	ARR
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4
PH 410	General Relativity	4
PH 460	Directed Study †	ARR

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 410	General Relativity	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
--------	-------------	-------

OE 360	Opto-mechanics and Optical Materials	4
EP 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowitz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
OE 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4

ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>



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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

The software engineering program prepares its graduates for many types of careers in the computing industry as well as for graduate study in software engineering and in closely related disciplines. Within a few years after completing the software engineering degree program, our graduates will:

- Advance beyond their entry-level position to more responsible roles, or progress towards completion of advanced degree(s).
- Continue to keep pace with advancements in their disciplines, and develop professionally in response to changes in roles and responsibilities.
- Demonstrate that they can collaborate professionally within or outside of their disciplines at local, regional, national, or international levels.
- Contribute to the body of computing products, services, or knowledge.

Software Engineering Student Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The software engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

SOFTWARE ENGINEERING

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric & Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term	Credit
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Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
Total		16

CSSE 220	Object-Oriented Software Development	4
MA 112	Calculus II	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems Design	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 371	Software Requirements Engineering	4
CSSE 372	Software Project Management	4
MA 381	Introduction to Probability with Statistical Applications	4
	Domain track course	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
HSS	Elective	4
	Domain track course	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 373	Formal Methods in Specification and Design	4
CSSE 375	Software Construction and Evolution	4
HSS	Elective	4
	Domain track course or free elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
MA 375	Discrete & Combinatorial Algebra II	4
	Domain track course	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Lang. Con	4
CSSE 376	Software Quality Assurance	4
MA	Elective	4
RH 330	Technical and Professional Communication	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 477	Software Architecture	4
CSSE 497	Senior Capstone Project I	4
HSS	Elective	4
	Domain track course or free elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 498	Senior Capstone Project II	4
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 499	Senior Capstone Project III	4
HSS	Elective	4
Free	Elective	4
Total		12

Total credits required: 192

Summary of graduation requirements for the software engineering major

To complete the major in software engineering a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE477, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA212, MA275, MA375, MA381; PH111, PH112, CHEM111; RH 131, RH330; CLSK100.
2. One additional CSSE elective course except CSSE 325, CSSE 473, CSSE 474, and CSSE 479. In addition, use of CSSE 49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.
3. A Domain Track set of courses. All of the courses for each of the [Domain Tracks](#) is listed on the CSSE website. That site also explains the procedures and deadlines by which a student must declare their Domain Track.

- 4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
- 5. Four credits of science electives, which can be any CHEM, GEOL, PH, or AB courses not already required for the software engineering major.
- 6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
- 7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

CSSE 120, Introduction to Software Development
CSSE 220, Object-Oriented Software Development
CSSE 230, Data Structures and Algorithm Analysis
CSSE 371, Software Requirements Engineering
CSSE 374, Software Design

Two additional courses in software engineering chosen from CSSE 372, 373, 375, 376, and 477.



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Industry Partners
Trustees
Parents

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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Air Force ROTC (Military)

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation-contact Air Force ROTC for more details.

SCHOLARSHIPS

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

- Profession of Arms** Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.
- Communications Skills** Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

General Military Courses

Freshman Year		Credit
AS 101	Found. of the US Air Force I	1
AS 101L	Leadership Laboratory	0
AS 102	Found. of the US Air Force II	1
AS 102L	Leadership Laboratory	0
AS 103	Found. of the US Air Force III	1
AS 103L	Leadership Laboratory	0

Sophomore Year		Credit
AS 201	Evol. of Air & Space Power I	2
AS 201L	Leadership Laboratory	0
AS 202	Evol. of Air & Space Power II	2
AS 202L	Leadership Laboratory	0
AS 203	Evol. of Air & Space Power III	2
AS 203L	Leadership Laboratory	0

Professional Officer Courses


Junior Year		Credit
AS 301	Air Force Lead. Studies I	4
AS 301L	Leadership Laboratory	0
AS 302	Air Force Lead. StudiesII	4
AS 302L	Leadership Laboratory	0
AS 303	Air Force Lead. Studies III	4
AS 303L	Leadership Laboratory	0

Senior Year		Credit
AS 401	Nat.Sec.Aff./Prep. for Active Duty I	4
AS 401L	Leadership Laboratory	0
AS 402	Nat.Sec.Aff./Prep. for Active Duty II	4
AS 402L	Leadership Laboratory	0
AS 403	Nat.Sec.Aff./Prep. for Active Duty III	4
AS 403L	Leadership Laboratory	0

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Humanities and Social Sciences

AREAS OF STUDY

Global Studies

Ideas and Art

Society and Values

Modern Languages

MAJORS

Economics

International Studies (second major only)

GERMAN TECHNICAL TRANSLATION CERTIFICATE

MINORS

Anthropology

Art

East Asian Studies

Economics

European Studies

Geography

German

History

Japanese

Language and Literature

Latin American Studies

Modern Languages

Music

Political Science

Philosophy and Religion

Psychology

Spanish

Theatre and Drama

Professors Bremmer, Carlson, Carvill, Casey, Chapman, Christ, Christensen, Dyer, Findley, Garcia, Gardner, Garner, Grose, Hartner, Hartnett, Heeter, Hirotani, House, Jern, Kim, Kukral, Letsinger, Livingston, Martland, Michel, Minster, Smith Roads, Summers, Taylor, Watt, and Williams.

MISSION STATEMENT

To enable our students to become creative, sophisticated thinkers, active citizens, and effective leaders in the global community, the department contributes to a broad liberal education, introducing students to a wide array of disciplines and traditions in the humanities and social sciences. In doing so, it provides learning experiences that, in addition to their intrinsic value, enrich a scientific and technical education.

Educational Objectives

Within the context of a liberal education, the department fosters in its students the desire and the ability to:

think critically

, forming cogent, informed opinions, defining and solving problems with an awareness that societal processes are complex and interactive;

communicate effectively

to diverse audiences, including those from other cultures and communities;

succeed in a global context

by understanding and adapting to diverse cultures, alternative points of view, and the challenges of globalization;

exhibit ethical and responsible leadership

as individuals, citizens, and professionals, committed to lifelong learning and achievement.

Disciplines

The HUMANITIES study what it means to be human within a contemporary or historical context. These

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

https://www.rose-hulman.edu/course-catalog/course-catalog-2015-2016/course-descriptions/humanities-and-social-sciences.aspx#intl-studies[1/20/2017 12:26:10 PM]

disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art and Art History	Anthropology
English and Literature	Archaeology
Foreign Languages(German, Japanese, and Spanish)	Economics
History	Geography
Music	Political Science
Philosophy and Religion	Psychology
Theater	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- **Global Studies (GS prefix):** Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- **Ideas and Arts (IA prefix):** Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.
- **Society and Values (SV prefix):** Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communication are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communication is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general **lower level courses (100 and 200 level)** tend to be broad surveys of particular subject areas within disciplines. **Upper level courses (300 and 400 level)** are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General

- All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

- All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted free elective transfer credit, but are not exempted from RH 131.
- **EXEMPTION:** An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. Any HSS course may be substituted for RH 131 for exempted students.
 1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic

Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.

2. Has received grades of B or higher in all high school English courses.

- **INTERNATIONAL STUDENTS:** International students for whom English is not their native language will be required to take an assessment test to gauge their written, oral, and listening proficiency in English. The purpose of this testing is to ensure that all students have the proper communication skills to advance successfully through the challenging Rose-Hulman curriculum. Based on this assessment, some students will be required to take CLSK121 College English. Those students must successfully complete CLSK121 prior to taking RH131 Rhetoric and Composition.

3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.
 1. A minimum of two terms of the same language (or the equivalent thereof) must be completed in order to apply foreign language credits toward Humanities and Social Sciences requirements. If only SP111, JP111 or GE111 is completed, that course will not be allowed to satisfy an HSS requirement."
 2. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.
 3. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three thematic categories as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each thematic category in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
 4. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
 5. Students may not earn foreign language credit in their native languages.
 6. Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. Minors

- Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

HELP WITH REQUIREMENTS

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, Spanish or Theatre and Drama by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in

the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

<i>Minor</i>	<i>Advisor</i>
Anthropology	Paul Christensen
Art	Steve Letsinger
East Asian Studies	Tim Grose
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter
Geography	Michael Kukral
History	Samuel Martland
Japanese	Maki Hirotani
Language and Literature	Caroline Carvill
Music	David Chapman
Latin American Studies	Gustavo Garcia
Philosophy and Religion	Dan Hartner
Political Science	Terrence Casey
Psychology	Alan Jern
Spanish	John Gardner
Theatre and Drama	Terence Hartnett

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Intro to East Asia 4R-OL-4C

Examines the changing political, economic, and cultural orders in East Asia.
(NOTE: formerly Intro to East Asian History)

GS 130 Introduction to Sustainability 4R OL 4C Prereq: Admission to HERE Program or Consent of Instructor

Surveys the fundamentals of sustainability in scientific, technical, and social contexts. Introduces students to the history of environmentalism and sustainability, along with the basics of ecology, climate assessment, natural cycles, life cycle analysis, environmental economics, and other concepts.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 185 Introduction to Anthropology 4R-OL-4C

Examines human adaptation and diversity as well as the development and variety of economic, political, religious, family, gender and expressive institutions.

GS 188 Introduction to Sociology 4R-OL-4C

Examines the foundations of sociology, paying particular attention to how humans shape and give meaning to the world in which we live.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Religion in China 4R-OL-4C

Introduces students to China's "official" religions (Buddhism, Taoism, Islam, Protestantism, and Catholicism) and the rich faith-based belief systems that are prominent in contemporary China (Shamanism, local deities, etc.).
(NOTE: Formerly Asian Religions and Philosophy)

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History since 1400 4R-OL-4C

Explores the history and interaction of major world regions since about 1400, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 231 Global Writing and Intercultural Communication 4R-OL-4C

Analyzes rhetorical traditions and communication styles within and across diverse cultures as well as global uses of English. Introduces students to theories and practices for communicating and collaborating across languages and cultures.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction's humanistic usefulness in examining human values from an "extra-species, extra-terrestrial" perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 243 Music History (Before 1650): Early European Music 4R OL 4C

Surveys the early music of Europe in the Medieval, Renaissance, and early Baroque periods and explores problems of accessing musical practices distant and distinct from our own.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS 324 Brazil Since 1500 4R-OL-4C

Provides a basic understanding of Brazilian history, major political parties and issues, geography, economy, and major social and cultural phenomena. Explores the creation of a multicultural society, Brazil's place in global systems, and other issues.

GS 327 Modern China 4R-OL-4C

Explores modern Chinese history from the Qing dynasty (1644-1911) to the present day.

GS 328 Pop Culture in China 4R-OL-4C

Examines the production and consumption of pop culture in China including literature, music, film, and print media.

GS 330 Contemporary Global Film 3R-3L-4C

Examines films outside of the Hollywood tradition with a consideration of the cultural, political, and economic influences that shape film.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 339 Contemporary Global Film 4R OL 4C

Surveys world cinema, emphasizing the importance of situating films within their historical and cultural background as well as recognizing the tensions between art and business in the film industry and how that shapes the medium.

GS 343 Musics of the World 4R OL 4C

Surveys the role of music in human cultures around the world and explores problems of accessing musical practices distant and distinct from our own, as well as thinking critically about those most familiar to us.

GS 350 International Trade and Globalization 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Prereq: SV 152 or SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Prereq: SV 151 or SV 152

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Tokyo 4R-OL-4C

Explores Tokyo from its origins to contemporary place as a "global capital" through history, geography, and culture.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 380 Pop Culture in China 4R-OL-4C

Examines the production and consumption of pop culture in China including literature, music, film, and print media.

GS 384 Japanese Society 4R-OL-4C

Introduces contemporary Japan from an anthropological perspective with an emphasis on the contradictions between hyper-modernity and traditionalism.

GS 386 Hispanic Culture and Civilization (Latin America) 4R-OL-4C Prerequisite: SP213 or permission of instructor

Introduces Hispanic culture and civilization from its origins to the present. Examines Hispanic Latin American societies through cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spanish Latin America. Taught in Spanish.

GS 387 Hispanic Culture and Civilization (Spain) 4R-OL-4C Prerequisite: SP213 or permission of instructor

Introduces Hispanic culture and civilization from its origins to the present. Examines Spanish society through

cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spain. Taught in Spanish.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 413 Nazi Germany: Fact and Fiction 4R 0L 4C

Examines the history of Nazi Germany as well as its representation in literature, film, and new media.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS 425 Cities and Technology in the Industrial Age 4R-OL-4C

Explores development of cities and the machines and systems that make them possible as human life became more and more urban and industrial from 1700 to the present. Compares urban growth and city life in different parts of the world.

GS 429 Greek and Roman Drama 4R-OL-4C

Examines drama in the classical world with special emphasis on the ways it was produced, staged, and acted. Close reading of plays by the Greek and Roman dramatists in translation.

GS 430 World Drama 4R-OL-4C

Examines drama from multiple cultures and time periods through a thematic lens.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS 470 Japanese Media 4R-OL-4C

Explores historical and contemporary media-related Japanese culture, both in visual and text communications.

GS 480 Leadership & Global Challenges 4R 0L 4C Prereq: Junior or senior standing; cross listed with EMGT536

Examines the art of leadership and its development in our increasingly globalized society by studying general theoretical approaches, with close attention to the unique challenges which globalization and cross cultural interactions impose upon leaders.

GS 485 Seminar on Japanese Society 4R-OL-4C

Provides students a firm grounding in Western intellectual engagement with Japan, particularly from an

anthropological perspective. Considers how Japan has been created and framed as a site of study through close readings of relevant ethnographic literature.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

GS CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

IDEAS AND ARTS -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R OL 4C

Introduces the methods and subject matter of philosophy through examination of some of the major problems and figures in classical and contemporary philosophy, including the nature of reality, the existence of God, the criteria of knowing, the nature of mind, and the foundations of morality.

IA 102 Critical Thinking and Introduction to Logic 4R OL 4C

Introduces students to philosophical methodology for examining the truth of claims and the quality of arguments used to defend them, including informal logic, i.e., the study of arguments in natural language, as well as formal logic, i.e., the study of inference with purely formal content, for the purpose of clarifying thinking and improving reasoning.

IA 128 Introduction to Islam 4R-OL-4C

Introduces the major figures, tenets, and cultural adaptations of Islam from Muhammad to the present day.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Communicating STEM to a Public Audience 4R-OL-4C

Examines the role of scientists and engineers as public intellectuals who can influence policy and public understanding. Emphasizes strategies for communicating technical knowledge to public audiences through popular media.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 3R-3L-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Fundamentals of Tonal Music 4R OL 4C

Pursues the initial stages of literacy in western tonal music, from rhythm and pitch to basic functional harmonic analysis.

IA 299 Introduction to Theater Arts 4R-OL-4C

Explores the whole mechanism of the modern theater and how it works, including principles and theories of theatrical art: production, direction, acting, scenic design, costume design, lighting design, makeup, sound and multimedia, and theater architecture.

IA 301 Philosophy of Mind 4R OL 4C

Focuses on the philosophical investigation of the nature of the mind, its relationship to the brain/body, the phenomenon known as consciousness, and a host of related issues including freedom of the will and its implications for moral responsibility, the relationship between philosophy, psychology, and neuroscience, the nature of self and personal identity, the possibility of machine and animal consciousness, and the idea of mental disorder.

IA 302 Philosophy of Religion 4R OL 4C

Examines the nature and existence of God and religious experience, the meaning of religious language, and the relationship between religion, science, and philosophy through analysis of classical and contemporary texts and teachings of major figures in theology and philosophy.

IA 303 Political Philosophy 4R OL 4C

Examines the philosophical foundations of social and political organization, governance, rights, liberty, law, individualism, and justice. This course explores fundamental questions about organized society by engaging with classical and contemporary texts dealing with the state of nature, the idea of a social contract and its opposition, democracy and its ideals, virtues, and difficulties, human rights and liberties, alternatives to democracy including communism and communitarianism, and feminist and individualist theories.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 325 Islam and Muslim Groups in China 4R-OL-4C

Examines the localization of Islam among China's ten officially recognized Muslim ethno-national groups.

IA 328 Ethnicity & the State in China 4R-OL-4C

Introduces students to the concepts of ethnic group, ethnicity, and nationalism and explores how ethnonational identity is institutionalized, constructed, and negotiated in contemporary China.

IA 330 Documentary Film 3R-3L-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 338 Medicine in Literature 4R-OL-4C

Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 340 Ethics in Human Communication 4R-OL-4C

Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 342 Modern Southern Fiction 4R OL 4C

Examines the major writers of the American South (both the modern and contemporary periods). Emphasizes recurrent social themes and fictional methods.

IA 343 Visual Rhetoric and Graphic Novels 4R-OL-4C

Explores the relationships between art and argument in comic books and graphic novels. Provides a vocabulary for students to discuss, analyze, and produce graphic communication, including the creation of their own mini-comic. (No drawing skills required).

IA 344 Writing in a Digital Age 4R-OL-4C

Examines the influence of digital technologies on the ways we read, produce texts, and interact. Emphasizes strategies for producing new media texts, such as podcasts, blogs, infographics, and “viral” videos.

IA 346 Music Theory II: Basic Form and Composition 4R-OL-4C Prereq: IA246 or consent of instructor

Explores intermediate topics in western tonal music and applies theoretical concepts to music composition. Forms studied and composed include simple classical and popular music genres.

IA 348 Music Performance 1R-OL-1R Prereq: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C S Prereq: SV 150 or SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C W Prereq: SV 151 or SV 152

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Prereq: SV 150 or SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C S (even years) Prereq: SV 150 or SV 151 or SV 152

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 371 Cognitive Psychology 4R OL 4C

Explores how the mind works using experimental findings and psychological models. Topics include perception, attention, memory, reasoning, decision making, and language.

IA 380 Literature and Human Rights in Latin America 4R-OL-4C

Explores testimonial narratives, which give a “voice to the voiceless,” allowing marginalized peoples to bear witness to human rights abuses. Examines testimonial narratives in terms of historical context, structure, narrative voice, and effectiveness in addressing situations of oppression and violence. Taught in English.

IA 388 Food, Culture, and the Self 4R-OL-4C

Examines food as a focus for deeper inquiry into culture, identity, national development, globalization and social change.

IA 389 Anthropology of Addiction 4R-OL-4C

Examines the concept of addiction – a frequently used yet rather imprecise term -- from a variety of perspectives to better understand this complex term and cultural concept.

IA 401 Philosophy of Science 4R OL 4C

Examines a range of philosophical questions about the methods, foundations, assumptions, and scope of science, including: How does science work? Can science reveal truths about the structure of the world? What is the scientific method and how is it different from other forms of knowledge acquisition, such as philosophy? What is a scientific explanation? What counts as evidence for a theory? What are scientific laws? These and other questions will be explored by engaging with a variety of classical and contemporary philosophical texts and arguments.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study

entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

IA 471 Computational Psychology 4R-OL-4C Pre: MA 381 or Consent of Instructor

Explores computational principles that can be used to explain human learning and develop intelligent machines. Includes programming assignments.

IA CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

SOCIETY AND VALUES -- Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 130 Introduction to Disability Studies 4R-OL-4C

Introduces disability studies, a multi-disciplinary field that identifies, challenges, and re-conceptualizes representations of disability. Topics may include disability history and policy, activism, bioethics, and the role of technology and engineering in our perceptions of disability.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 150 Introduction to Microeconomics 4R-OL-4C F,W,S

Analyzes the market behavior of buyers and sellers. Topics include demand and supply, costs, competition, oligopoly, monopoly, economic efficiency and resource allocation, the effects of government intervention, and international trade. A student cannot take both SV 150 and SV 151, Principles of Economics, for credit.

SV 152 Introduction to Macroeconomics 4R-OL-4C F,W,S

Analyzes the performance of the entire economy. Topics include demand and supply, GDP, unemployment and inflation, the impact of monetary and fiscal policy, business cycles, determinants of economic growth, and international finance. A student cannot take both SV 152 and SV 151, Principles of Economics, for credit.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

A broad survey of the scientific study of mind and behavior. Topics include learning, perception, emotion, motivation, memory, childhood development, personality, social behavior, and psychological disorders.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in

society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV244 Western Music in the Baroque, Classical, Romantic Eras 4R-OL-4C

Surveys composers, events, and genres of western art music in the “common practice period” and their contexts in world history.

SV245 Western Music in the 20th Century 4R-OL-4C

Surveys composers, events, and genres in the Modern and Postmodern periods and their contexts in world history.

SV246 Popular Music in the Era of Recorded Sound 4R-OL-4C

Surveys the impact of audio recording revolutions of the 20th century on American popular music and explores relationships between technology and its competing and complementary human interests, such as aesthetics, politics, tradition, commerce, law, ethics, among many others.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R OL 4C

Examines the ethical issues faced by professional businesspeople and engineers working in a global corporate context. Issues include the development and use of codes of professional ethics, the social responsibilities of corporations, the autonomy of professionals, whistleblowing and corporate loyalty, environmental obligations of corporations and professionals, standards of conduct in international business, and the impact of technology on our world.

SV 304 Bioethics 4R OL 4C

Examines the major moral issues in the development and practice of biomedicine and biomedical research through the analysis of philosophical and ethical theory as well as analysis of real cases of morally questionable practice in biomedicine. Topics include the autonomy and rights of patients, physicians, and researchers, informed consent and experimentation with humans and animals, the moral status of genetic and reproductive controls and interventions, the extension and termination of life, and the allocation of scarce medical resources.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the “Boom” in Latin American fiction (the expanded popularity beginning in the 1960’s), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 340 American Drama 4R-OL-4C

Surveys American drama from the colonial period to the present.

SV 341 African-American Drama 4R-OL-4C

Surveys African-American drama from the early 19th century to the present.

SV 342 Modern European Drama 4R-OL-4C

Surveys modern European drama from about 1870 to the present.

SV 345 Presidential Election Rhetoric 4R-OL-4C

Increases students’ awareness and understanding of the U.S. Presidential election process, candidates, campaign issues, campaign advertising, debates, and the role of the news media. Focuses on analyzing and producing rhetoric associated with presidential campaigns.

SV 351 Managerial Economics 4R-OL-4C Prereq: SV 150 or SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. Students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Prereq: SV 151 or SV 152

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Prereq: SV 150 or SV 151

Examines the influence of market structure and competition policy on business firms’ decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 371 Social Psychology 4R OL 4C

Explores how people's behavior, feelings, and thoughts are influenced by their social environments. Topics include attitude formation, prejudice, relationships, group behavior, conformity, altruism, and aggression.

SV 373 Abnormal Psychology 4R-OL-4C

Explores the diagnosis, causes, and treatments of psychological disorders.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and evolution, the fossil record, and genetics; compares human behavior with other primates; and explores the extent and causes of human physical diversity.

SV 389 Anthropology of Sports 4R-OL-4C

Introduces the study of sport through a critical anthropological lens. Sport is used to contextualize gender, health, technology, ethnic difference, nationalism, sexuality, and socioeconomic class.

SV 402 Human Nature 4R OL 4C

Examines what it means to be human by examining major philosophical texts in the Western tradition in conjunction with recent developments in psychology and cognitive science. The central issues include happiness and the good life, morality, justice, and the structure of human social institutions.

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C F (odd years) Prereq: SV 150 or SV 151 or SV 152

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

SV 472 Studying Human Behavior 4R-OL-4C

Introduces students to the methods of behavioral science by having them design, run, and analyze actual psychology experiments.

SV CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

COMMUNICATION

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis of texts and images, research methods, and the conventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Prereq: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

SPECIAL TOPICS AND DIRECTED STUDY

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS

Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX456 Seminar for HSS Senior Project 2R-OL-2C F Prereq: Economics or International Studies major and Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX457 Directed Study for HSS Senior Project 2R-OL-2C Arranged Prereq: XX456 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double majors.

MODERN LANGUAGES

(NOTE: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Prereq: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Prereq: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Prereq: GE 213

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Prereq: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C

Summer Prereq: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Prereq: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-OL-4C S

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-OL-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

GS CPT / IA CPT / SV CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

HSS MAJORS

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning OutComes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 - A. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 - B. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 - C. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 - A. Explain the global causes or effects of an action or decision by nation-states, corporations, groups

of people, or other actors

B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study

3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences

A. Assemble and evaluate resources for research in international studies.

B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA233	World Literature
GS163	International Relations
GS285	Humans and Culture
GS291	World Geography
SV150 OR SV152	Introduction to Microeconomics/Macroeconomics
GS223	World History since 1400

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

a. International Political Economy: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose at least three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General List

IA353	History of Economic Thought
GS322	Industrial Revolution in a Global Context
GS350	International Trade and Globalization
GS351	International Finance
GS352	Economic Growth and Development
GS361	Politics of the Global Economy
SV328	Comparative Business History
SV354	Environmental Economics

Regional List

GS128	Introduction to East Asia
GS161	Comparative Politics
GS222	Modern Latin American
GS366	European Union
GS363	European Politics and Government
GS399	Geography of the Middle East
GS492	Geography of Africa

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

a. Comparative Cultures: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

- GS322 Industrial Revolution in Global Context
- GS333 Travel in World Literature
- GS334 Global Novel in the 20th Century
- GS432 Literature of the Global Economy
- GS462 Postcolonial Literature
- SV191 Cultural Geography
- SV201 Religion and Ecology

Regional list (including but not limited to the following courses)

- IA311 Topics in German Culture I
- GS128 Introduction to East Asia

- GS222 Modern Latin America
- GS313 Contemporary Spain
- GS327 Modern China
- GS335 Arabic Literature
- GS379 Japanese Culture
- GS391 Contemporary Europe
- GS442 Art History: Renaissance to Modern
- GS492 Geography of Africa

- 1. Individualized Major: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS MINORS

MINOR IN ANTHROPOLOGY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

- 1. Five Courses in Anthropology
- 2. The following course is required:
 - GS 185 Introduction to Anthropology
- 3. Four additional courses from the list below:
 - GS 128 Introduction to East Asia
 - GS 368 Tokyo
 - GS 379 Japanese Popular Culture
 - GS 384 Japanese Society
 - GS 385 Japanese Society Seminar
 - IA 388 Food, Culture, and the Self
 - IA 399 Anthropology of Addiction
 - SV 386 Human Evolution
 - SV 399 Anthropology of Sports
 - XX 399 Special Topics

- XX 499 Directed Study
- 4. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- 5. Substitutions may be made with the approval of the Minor Advisor

MINOR IN ART

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

1. Five Courses in Art
2. The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242 Visual Arts in Civilization
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Advisor

Courses

- GS442 Art History: Renaissance to Modern
- IA142 Drawing
- IA148 Beginning Photography
- IA244 Design and Color
- SV242 Visual Arts in Civilization

MINOR IN EAST ASIAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS128 Introduction to East Asian History
 - GS207 Asian Religions and Philosophy
 - GS327 Modern China
 - GS379 Japanese Popular Culture
 - GS368 Tokyo
 - GS380 Pop Culture in China
 - GS384 Japanese Society
 - GS385 Japanese Society Seminar
 - IA380 Islam and Muslim Groups in China
 - IA328 Ethnicity and State in China
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the minor advisor.

MINOR IN ECONOMICS

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Introduction to Microeconomics (SV 150);
 - b. Introduction to Macroeconomics (SV 152);
 - c. Intermediate Microeconomics (IA 350) or Intermediate Macroeconomics (IA 351);
 - d. Two additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- GS350 International Trade and Globalization
- GS351 International Finance
- GS352 Economic Growth and Development
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- IA352 Game Theory
- IA353 History of Economic Thought
- IA450 Mathematical Economics
- IA453 The Entrepreneur
- SV150 Introduction to Microeconomics
- SV152 Introduction to Macroeconomics
- SV351 Managerial Economics
- SV352 Money and Banking
- SV353 Industrial Organization
- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX456/457 Senior Project

MINOR IN EUROPEAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS313 Contemporary Spain
 - GS337 Shakespeare's Europe
 - GS363 European Politics and Government
 - GS366 The European Union
 - GS431 Literary London
 - GS469 Contemporary British Fiction and Film
 - GS491 Geography of Europe
 - IA311 Topics in German Culture I
 - IA337 European Romanticism
 - SV222 Western Civilization to 1500
 - SV223 Western Civilization from 1500 to the Present
 - SV291 Medieval Europe
 - SV413 Contemporary Germany
 - XX399 Special Topics
 - XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN GEOGRAPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS191 Geography of Middle East
- GS222 Modern Latin America

- GS291 World Geography
- GS327 Modern China
- GS391 Contemporary Europe
- GS491 Geography of Europe
- GS492 Geography of Africa
- SV191 Cultural Geography
- SV291 Medieval Europe
- XX399 Special Topics
- XX499 Directed Study

MINOR IN HISTORY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS221 Colonial Latin America
- GS223 World History since 1400
- GS222 Modern Latin America
- GS324 Brazil Since 1500
- GS325 Cities and Technology
- GS413 Nazi Germany: Fact and Fiction
- GS422 Industrial Revolution in Global Context
- SV222 Western Civilization to 1500
- SV223 Western Civilization since 1500
- SV322 Disasters and Modern Society since 1700
- XX399 Special Topics
- XX499 Directed Readings

MINOR IN LANGUAGE AND LITERATURE

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and RH 330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS237 Science Fiction
- GS334 Travel in World Literature
- GS335 The Global Novel in the Twentieth Century
- GS336 Literature of War
- GS337 Shakespeare's Europe
- GS338 Contemporary Arabic Literature in Translation
- GS339 Contemporary Global Film
- GS412 Topics in German Culture II
- GS431 Literary London
- GS432 Literature and Film of the Global Economy
- GS462 Postcolonial Literature
- GS469 Contemporary British Fiction and Film
- IA230 Fundamentals of Public Speaking
- IA231 Introduction to Poetry
- IA232 African American Music in American Literature
- IA233 World Literature
- IA234 Major American Writers
- IA235 Major British Writers
- IA237 Introduction to Drama

- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature
- IA337 European Romanticism
- IA338 Medicine in Literature
- IA339 Rebellion in American Literature
- IA341 Steinbeck and American Society
- IA342 Modern Southern Fiction
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Gender, Work & Popular Culture
- SV334 Utopian Thought and Literature
- SV336 Contemporary American Fiction
- SV337 20th century American Novel
- SV339 Literature and the Environment
- SV234 The American Dream
- XX399 Special Topics
- XX499 Directed Study

MINOR IN LATIN AMERICAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS221 Colonial Latin America
 - GS222 Modern Latin America
 - GS313 Contemporary Spain
 - GS324 Brazil Since 1500
 - IA332 Don Quixote
 - SV338 Latin American Fiction: The Boom and Beyond
 - XX399 Special Topics
 - XX499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN MODERN LANGUAGES (GERMAN, JAPANESE, AND SPANISH)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture
IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation
Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413
Japanese Language and Culture X/XI/XII

XX 399 Special Topics

XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.

Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

MINOR IN MUSIC

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. Twenty credits (the equivalent of five courses) in Music. IA246, IA346, SV244, and four credits of IA348 are required.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Music Theory courses (*both required*):

- IA246 Music Theory I: Fundamentals of Tonal Music

- IA346 Music Theory II: Basic Form and Composition (*pre-requisite: IA246*)

Students who have taken music theory before attending Rose Hulman may choose to take a Theory I placement test in order to be granted admittance to Music Theory II. Students who successfully pursue this option must then substitute for Music Theory I another music related course, as approved by the Music Advisor.

Music History and Culture courses (*one required; student may chose the other*):

- GS243 Early European Music (Before 1650)

- SV244 Western Music of the Baroque, Classical, and Romantic Eras (*required*)

- SV245 Western Music in the 20th Century

- SV246 Popular Music in the Era of Recorded Sound

- GS343 Musics of the World

Music Performance (*four credits required*):

- IA348 Music Performance (*pre requisite: consent of the ensemble director[s]*)

One credit represents one academic term of satisfactory participation in one accredited Performing Groups (Concert Band, Jazz Ensemble, String Ensemble/Orchestra, and Chorus). Maximum of two credits (that is, participation in two ensembles) per term. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for "satisfactory participation" will be provided to the candidate by the ensemble directors.

MINOR IN PHILOSOPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy has the following requirements:

1. Five courses in Philosophy, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Philosophy Courses:

- IA101 – Introduction to Philosophy
- IA102 – Critical Thinking & Introduction to Logic
- IA401 – Philosophy of Science
- IA302 – Philosophy of Religion
- IA301 – Philosophy of Mind
- IA303 – Political Philosophy
- SV402– Human Nature
- SV303 – Business & Engineering Ethics
- SV304 – Bioethics
- XX399 – Special Topics
- XX499 – Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS161 Comparative Politics
- GS163 International Relations
- GS361 Politics of the Global Economy
- GS366 The European Union
- SV166 American Politics and Government
- SV369 British Politics and Government
- IA463 Seminar on America's Future
- XX399 Special Topics
- XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Principles of Psychology (SV 171).
2. Four other psychology courses.
3. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
4. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
5. Substitutions may be made with the approval of the Minor Adviser.

Courses:

- SV 171 Principles of Psychology
- SV 372 Social Psychology
- SV 472 Studying Human Behavior
- SV 373 Abnormal Psychology

- IA 371 Cognitive Psychology
- IA 471 Computational Psychology
- IA 301 Philosophy of Mind

Minor in Theater and Drama

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

Requirements:

1. Five courses (20 credits) in Theater and Drama.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the minor advisor.

Courses:

- IA 299 Introduction to Theater Arts
- IA 237 Introduction to Drama
- IA 240 Introduction to Shakespeare
- SV 340 American Drama
- SV 341 African American Drama
- SV 342 Modern European Drama
- GS 337 Shakespeare's Europe
- GS 429 Greek and Roman Drama
- GS 430 World Drama

GERMAN TECHNICAL TRANSLATOR'S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute's degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.

- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60



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[Trustees](#)
[Parents](#)

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Army ROTC (Military)

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

CURRICULUM

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College,

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

ADVANCED COURSE

Freshman Year

		Credit
MS 101	Leadership and Personal Development	1
MS 102	Introduction to Tactical Leadership	1
MS 103	Basic Tactical Leadership	1
		3

Sophomore Year

		Credit
MS 201	Innovative Team Leadership	2
MS 202	Foundations of Tactical Leadership	2
MS 203	Foundations of Tactical Leadership II	2
		6

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Summer

MS 206	ROTC Basic Camp	0
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Junior Year


		Credit
MS 301	Adaptive Team Leadership	4
MS 302	Leadership Under Fire	4
MS 303	Leadership Under Fire II	4
		12

Senior Year

		Credit
MS 401	Developing Adaptive Leaders	4
MS 402	Leadership in a Complex World	4
MS 403	Leadership in a Complex World II	4
		12

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training..

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Industry Partners
Trustees
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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose- Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

- Biology
- Biochemistry
- Biomathematics
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
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- Army ROTC (Military)
- Pre-Professional Programs



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[Parents](#)

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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Air Force ROTC (Military)

LT Col Morgan III, CAPT Jeffers

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Prereq: None

This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Prereq: AS 101 or instructor permission

This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Prereq: AS 102 or instructor permission

This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Prereq: Enrollment in AS 101, AS 102, or AS 103

Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Prereq: AS 103 or instructor permission

This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Prereq: AS 201 or instructor permission

This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Prereq: AS 202 or instructor permission

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

This course is a continuation of the winter quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Prereq: Enrollment in AS 201, AS 202, or AS 203

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Prereq: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Prereq: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Prereq: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Prereq: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Prereq: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Prereq: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Prereq: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Prereq: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Army ROTC (Military)

LTC Eric Walthall and MSG Zoleske

FRESHMAN YEAR Basic Course

MS 101: Introduction to the Army and Critical Thinking 1R-3L-1C F Prereq: None

MS 101 introduces Cadets to the personal challenges and competencies that are critical for effective leadership. Cadets learn how the personal development of life skills such as critical thinking, time management, goal setting, stress management, and comprehensive fitness relate to leadership, and the Army profession.

MS 102: Adaptive Leadership and Professional Competence 1R-3L-1C W Prereq: MS 101 or Instructor Permission

MS 102 introduces Cadets to the personal challenges and competencies that are critical for adaptive leadership. Cadets learn the basics of the communications process and the importance for leaders to develop the essential skills to effectively communicate in the Army. Students will examine the Army Profession and what it means to be a professional in the U.S. Army.

MS 103: Basic Tactical leadership 1R-3L-1C S Prereq: MS 101 and 102 or Instructor Permission

MS 103 continues the exploration of leadership fundamentals and examines the leadership process as affected by individual differences and styles, group dynamics, and personality behavior of leaders. Students will experience an introduction of fundamental leadership concepts, and examine factors that influence leader and group effectiveness. Students will fully explore the basic soldier skills and squad level tactical operations. Students participate in briefings and hands-on practical exercises. Attention is devoted to development of leadership potential through practical exercises both in and out of the classroom.

SOPHOMORE YEAR Basic Course

MS 201: Leadership and Decision Making 2R-3L-2C F Prereq: MS 101, 102, and 103 or Instructor Permission

MS 201 explores the dimensions of creative and innovative tactical leadership strategies and styles by examining team dynamics and two historical leadership theories that form the basis of the Army leadership framework. Aspects of personal motivation and team building are practiced planning, executing and assessing team exercises.

MS 202: Army Doctrine and Team Development 2R-3L-2C W Prereq: MS 201 or Instructor Permission

MS 202 examines the challenges of leading teams in the complex operational environment. The course highlights dimensions of terrain analysis, patrolling, and operation orders. Further study of the theoretical basis of the Army Leadership Requirements Model explores the dynamics of adaptive leadership in the context of military operations. Cadets develop greater self awareness as they assess their own leadership styles and practice communication and team building skills.

MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Prereq: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Cadet Initial Entry Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive

Air Force ROTC (Military)

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Biology & Biomedical Engineering

Biomathematics

Chemical Engineering

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Civil Engineering

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Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Cadet Initial Entry Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

JUNIOR YEAR Advanced Course

MS 301: Training Management and the Warfighting Functions 3R-3L-4C F Prereq: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 Cadets will study, practice, and apply the fundamentals of Army Leadership, Officership, Army Values and Ethics, Personal Development, and small unit tactics at the platoon level. At the conclusion of this course, Cadets will be capable of planning, coordinating, navigating, motivating and leading a squad and platoon in the execution of a mission during a classroom PE, a Leadership Lab, or during a Leader Training Exercise (LTX).

MS 302: Applied Leadership in Small Unit Operations 3R-3L-4C W Prereq: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when under fire are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Cadet Leader Course (CLC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Prereq: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for CLC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

Overview of CLC: Cadet Leader Course

Summer Term Only

The purpose of the course is to train U.S. Army ROTC Cadets to Army standards, to develop their leadership skills, and to evaluate their officer potential. The 29-day course starts with individual training and leads to collective training, building from simple to complex tasks. This building-block approach permits integration of previously-learned skills into follow-on training. This logical, common-sense training sequence is maintained for each training cycle. Every day at CLC is a day of training.

SENIOR YEAR- Advanced Course

MS 401: Mission Command and Ethics 3R-3L-4C F Prereq: MS 303

MS 401 is an advanced course that places primary emphasis on Officership with our MS IV cadets who are our educational main effort; MS 401 and 402 together refine and ultimately completes the Cadet-to commissioned officer transition. In MS 401 Mission Command and ethics is stressed in order to assist the Cadet in further embracing their future role as an Army officer.

MS 402: Mission Command and the Army 3R-3L-4C W Prereq: MS 401

MS 402 and MS 403 are the culmination of a four-year sequential, progressive, challenging developmental leadership experience. It is during this quarter and MSL 403 that the Cadet is undergoing final preparation for the duties and responsibilities of a commissioned officer along with their integration into the Army. The emphasis is placed on critical knowledge, skills, abilities and competencies skills newly commissioned officers will need to succeed in their first unit of assignment, and the modern operating environment where they will be expected to plan, prepare, execute, and assess platoon-level training strategies and more to enable mission accomplishment.

MS 403: Leadership in a Complex World II 3R-3L-4C S Prereq: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

MS 497: Military Science Independent Study Variable Credit Prereq: MS 301, 302, 303 and Instructor Permission

MS 497 provides ROTC cadets who have completed their Cadet Leader Course the opportunity to conduct detailed research and independent study on a current problem or topic associated with the military. Program of study will be arranged individually with the Professor of Military Science.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies

and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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[Trustees](#)
[Parents](#)

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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Biology & Biomedical Engineering

Biology

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed BIO110, BIO120 or BIO130 cannot receive credit for taking BIO101.

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for BIO or BE majors and not as an BIO elective.

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed BIO course.

The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for BIO205 cannot earn credit for BIO210 or BIO230 without departmental consent.

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

Discusses the essential properties of eubacteria and archaea. Bacterial nutrition, growth, genetics and structural

Physics

and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

BIO 230 Cell Biology 3R-3L-4C S Prereq: BIO 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

BIO 264 Introduction to Environmental Science 4R-0L-4C W Prereq: CHEM 113 and CHEM 113L

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

BIO 310 Plant Structure & Function 3R-3L-4C S Prereq: BIO 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

BIO 320 Ecology 3R-3L-4C F Prereq: BIO 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

BIO 330 Evolutionary Biology 4R-0L-4C W Prereq: BIO 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

BIO 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Prereq: BIO 120, and Jr/Sr standing or consent of instructor

Designed to introduce biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

BIO 399 Practice of Science 4R-0L-4C Prereq: RH 330 and MA 223, or consent of instructor

This course focuses on skills required for implementing scientific research, including reading the primary literature, experimental design, scientific writing, oral presentations, research proposal writing, poster presentations, and investigation of research programs (through seminars or individual meetings). Each student chooses a project and research mentor by the end of the course.

BIO 410 Infection and Immunity 4R-0L-4C Arranged Prereq: BIO 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

BIO 411 Genetic Engineering 4R-0L-4C Arranged Prereq: BIO 205 or BIO 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

BIO 421 Applied Microbiology 4R-0L-4C Arranged Prereq: BIO 110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

BIO 431 Genomics and Proteomics 4R-0L-4C S Prereq: BIO 205 or BIO 210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

BIO 441 Virology 3R-3L-4C Prereq: BIO 110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

BIO 451 Cancer Biology 4R-0L-4C Prereq: BIO 205 or BIO 210 or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

BIO 461 Evolutionary Medicine 4R-0L-4C Arranged Prereq: BIO 130, and BIO 205 or BIO 210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

BIO 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged Prereq: BIO 205 or BIO 210 or consent of instructor

Strategies and methods used to identify and understand the genetic and molecular bases of inherited human disease are addressed. Topics include, human population genetics, pedigrees, genetic and physical mapping of human genes, linkage analysis, and diagnostic testing. Primary literature is routinely utilized.

BIO 491 Special Topics in Biology XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed BIO course.

BIO 492 Directed Study in Biology XR-XL-XC Arranged Prereq: Consent of instructor

Covers biology material of mutual interest to the student and instructor which cannot be experienced in any other listed BIO course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the BBE department is required to use this course to fulfill BIO elective credit requirements.

BIO 496 Senior Thesis Research I 0R-6L-2C F,W,S Prereq: BIO 399 and consent of instructor

Initiation of senior thesis under the direction of an BBE faculty mentor. Major tasks include creation and submission of a research proposal and piloting procedures. Additional requirements for adequate progress determined by each faculty mentor.

BIO 497 Senior Thesis Research II 0R-12L-4C F,W,S Prereq: BIO 399 and consent of instructor

Continuation of research under the direction of an BBE faculty mentor. Major tasks include data acquisition and methodological refinement. Additional requirements for adequate progress determined by each faculty mentor.

BIO 498 Senior Thesis Research III 0R-12L-4C F,W,S Prereq: BIO 399 and consent of instructor

Continuation of research under the direction of an BBE faculty mentor. Major tasks include data acquisition and preliminary analysis. Additional requirements for adequate progress determined by each faculty mentor.

BIO 499 Senior Thesis Research IV 0R-6L-2C W Prereq: BIO 399 and consent of instructor

Completion of senior thesis under the direction of an BBE faculty mentor. Major tasks include final analysis, public presentation of results, and submission of the written thesis. Additional requirements for adequate progress determined by each faculty mentor.

BIO CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4C S Prereq: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE 201 Biomedical Instrumentation and Measurements 3R-3L-4C W, S Prereq: BE 100, ES 203

Discussion of measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors

(temperature, force, pressure, velocity, etc), and basics of microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I 3R-3L-4C W Prereq: BIO 120, BIO 205

An analysis of neural, muscular, and endocrine physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Prereq: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of cradle to cradle design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II 3R-3L-4C S Prereq: BE310

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3C W Prereq: ES 201, EM 204, and BE 201, or consent of instructor Co: BE 351 or BE352, and BE 361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Signal Processing 3R-3L-4C F Prereq: BE 201, ES 203

This course introduces the fundamental of biomedical signal processing strategies. Topics include data acquisition, A/D and D/A conversion, digital filter design, time-frequency analysis, and I/O interfaces. Multichannel data processing and high dimensional data analysis techniques are also covered. Lectures will be accompanied by data analysis assignments and projects using MATLAB, LabVIEW, and microcontrollers.

BE 350 Biocontrol Systems 4R-0L-4C Prereq: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE 351 Biomedical Engineering Lab 1R-3L-2C Coreq: BE 331 and BE 361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE 352 Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE 331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 353 Biomaterials Lab 0R-3L-1C Prereq: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE 361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 385 Quality Methods 4R-0L-4C S Prereq: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (Pcharts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran,

and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as MA 385

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Prereq: BE 201, Coreq: EM 204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 400 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Prereq: BE 390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Prereq: BE 410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Prereq: BE 420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 482 Bioengineering Statistics 4R-0L-4C Prereq: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Prereq: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F,W,S Prereq: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing 3R-3L-4C W Prereq: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Analysis of Physiological Systems I 3R-3L-4C W Prereq: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Analysis of Physiological Systems II 3R-3L-4C S Prereq: Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 520 Introduction to Brain Machine Interfaces 3R-3L-4C S Prereq: BE340 or ECE480

This course is an introduction to the basics of motor cortical functions related to voluntary and imagery movements, evoked response potentials, invasive vs. noninvasive electrode design considerations, quantitative EEG analysis techniques used in clinical settings, and the applications of brain-machine interfaces/brain-computer interfaces in the restoration of mobility, communication and motor function.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Prereq: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Prereq: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3 R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535 Biomedical Optics 4R-0L-4C W Prereq: PH 113, MA 212, and SR standing or GR standing

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 435 and OE 535. Cross-listed with OE 535.

BE 539 Multiscale Biomechanics 3R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and BE340, or BE340 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as ECE584.

BE 543 Neuroprosthetics 3R-3L-4C Prereq: BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Prereq: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Prereq: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Prereq: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Prereq: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 565 Experimental Methods in Tissue-Biomaterial Interactions 3R-3L-4C S Prereq: BE 361, or consent of instructor

This course focuses on teaching students experimental methods used for investigations of tissue-biomaterial interactions. Topics include bioethics issues associated with experiments on cells, tissues, animals, and people; biosafety issues associated with cells/tissues from animals and humans; the design, critique, and statistical analysis of experiments. Students conduct hands-on investigations of cell-biomaterial interactions which require the use of common laboratory equipment, aseptic technique, mammalian cell culture, and current molecular methods to investigate cell viability, structure, and function.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Prereq: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 Selected Topics F,W,S

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.

BE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or

practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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electives also provides biomathematics students with an opportunity to apply knowledge gained through BMTH coursework. The following focus areas are illustrative examples to consider.

Applied Mathematics

BE 350	Biocontrol Systems
MA 275/375	Discrete and Combinatorial Algebra I/II
MA 332	Intro. to Computational Science [required for major]
MA 330	Vector Calculus
MA 342	Computational Modelings
MA 366	Real Analysis
MA 367	Functions of a Complex Variable
MA 436	Introduction to Partial Differential Equations
MA 472	Graph Theory
MA 491	Introduction to Mathematical Modeling

Biochemistry

BMTH 312	Bioinformatics
BMTH 310	Mathematical Biology
CHEM 251/252/253	Organic Chemistry I/II/III
CHEM 326	Bioanalytical Chemistry
CHEM 330/331	Biochemistry I/II
CHEM 430	Advanced Biochemistry

Bioinformatics & Biostatistics

BMTH 312	Bioinformatics
MA 381	Intro. to Probability with Statistics [required for major]
MA 382	Intro. to Statistics with Probability
MA 382	Engineering Statistics II
MA 386	Statistical Programming
MA 482	Bioengineering Statistics

Biomechanics

BE 361	Biomaterials
BE 525	Biomedical Fluid Mechanics
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopedic Biomechanics

Biophysics

PH 302	Biophysics
BE 525	Biomedical Fluid Mechanics

Cellular and Molecular Biology

BIO 220/230	Prokaryotic/Eukaryotic Cell and Molecular Biology [required for major]
BIO 205	Cellular Physiology
BIO 411	Genetic Engineering
BIO 421	Applied Microbiology
BIO 431	Genomics and Proteomics
BMTH 310	Mathematical Biology
CHEM 455	Natural Products [offered irregularly]

Computational Biology

BMTH 310	Mathematical Biology
BMTH 413	Computational Biology
CSSE 220	Object Oriented Software Development
CSSE 333	Database Systems
CSSE 403	Programming Language Paradigms
CSSE 431	Artificial Intelligence
MA/CS 335	Introduction to Parallel Computing
MA 342	Computational Modeling
MA 433	Numerical Analysis
MA 435	Finite Difference Methods
MA/CS 473	Design and Analysis of Algorithms

Ecology

BIO 130	Evolution and Diversity
BIO 264	Introduction to Environmental Science
BIO 320	Ecology
BMTH 310	Mathematical Biology
CHEM 371	Environmental Analytical Chemistry

Epidemiology & Pathology

BE 310/320	Analysis of Physiological Systems I/II
BIO 410	Infection and Immunity
BIO 441	Virology
BIO 451	Cancer Biology
BIO 461	Evolutionary Medicine
BIO 471	Genetic and Molecular Analysis of Inherited Human Disease
BMTH 310	Mathematical Biology

Evolution

BIO 130	Evolution and Diversity
BIO 330	Evolutionary Biology
BIO 461	Evolutionary Medicine
SV 386	Human Evolution

Imaging and Optics

BE 435	Biomedical Optics
ECE 480	Introduction to Image Processing
BE 541	Medical Imaging Systems
MA 439	Mathematical Methods of Image Processing
PH 302	Biophysics

Medicine

BIO 120	Comparative Anatomy and Physiology
BIO 410	Infection and Immunity
BIO 441	Virology
BIO 451	Cancer Biology
BIO 461	Evolutionary Medicine
BIO 471	Genetic and Molecular Analysis of Inherited Human Disease
BE 541	Medical Imaging Systems
CHEM 251/252/253	Organic Chemistry I/II/III
CHEM 330/331	Biochemistry I/II
CHEM 420	Advanced Biochemistry

Physiology

BIO 120	Comparative Anatomy and Physiology
BIO 205	Cellular Physiology
BE 310/320	Analysis of Physiological Systems I & II
BE 520	Introduction to Brain Machine Interfaces



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Chemical Engineering

Professors Anastasio, Chenette, G. Hariri, M.H. Hariri, D. Henthorn, K. Henthorn, McClellan, Neumann, Nolte, Reizman, Sauer, and Serbezov.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Prereq: None
An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 1R-0L-0C F Prereq: sophomore standing in Chemical Engineering
Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F Prereq: CHEM 113 or concurrent registration in CHEM 112, MA 113 or concurrent registration, and PH 111 or concurrent registration
An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Prereq: CHE 201
The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Prereq: CHE 201
Physical properties of fluids, fluid statics, laminar and turbulent flow, boundary layer concept, flow past objects and flow through porous media. Design of pipe networks and pumps. High speed ideal gas flow. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Prereq: CHE 202, MA 211 Coreq: CHE 110
First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F,W Prereq: CHE 303, MA 212
Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Prereq: CHE 110, MA 211, MA 212 or concurrent enrollment
The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Prereq: CHEM 115 or consent of instructor

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Prereq: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304

Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Prereq: CHE 320, CHE 304

Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Prereq: CHEM 360 and CHE 304

The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Prereq: Senior Standing in Chemical Engineering

Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Prereq: CHE 321, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Prereq: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Prereq: CHE 321

Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Prereq: CHE 416, CHE 404

Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Prereq: CHE 417 or consent of instructor

Completion of an open-ended design project that will include written and oral communication of intermediate

results and a final written report.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W Prereq: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F Prereq: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 460 Particle Technology 4R-0L-4C Prereq: MA 212, CHE 202, CHE 301

Introduction to the fundamentals of particle technology including particle characterization, transport, sampling, and processing. Students will learn about the basic design and scale-up of some industrial particulate systems (including fluidized beds, mixers, pneumatic conveying systems, cyclone separators, and hoppers) as well as environmental and safety issues related to particulate handling.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Prereq: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Prereq: CHE 303 or CHEM361 or CE205 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S Prereq: CHE303

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F,W,S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F,W,S Prereq: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

CHE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

CHE 502 Transport Phenomena 4R-0L-4C Prereq: CHE 321 or consent of instructor

Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of

temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W Pre: CHE 321 or consent of instructor

Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 515 Nanomaterials Science and Engineering 4R-0L-4C Prereq: CHE 315 or ME 328

Current research trends and industrial activity in the field of nanotechnology. Contains an overview of nanoscale characterization and production methods and emphasizes the roles that chemical functionality, thermodynamics, and physics play in determining the unique properties of nanoscale materials systems. Independent student reviews of current research literature form an integral part of the course.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Cross-listed with EP 511, ME 519, and ECE 519.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: BIO110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: BIO110, CHE 321 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Institute of Technology**
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CATALOG HOME

Chemistry and Biochemistry

Professors Allison, Brandt, R. DeVasher, Erwin, Hoffman, Morris, Mottel, Mueller, Tilstra, Weatherman and Wilson.

CHEM 111 General Chemistry I 3R-3L-3C F,W,S Prereq: None; Coreq: CHEM111L
Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 111L General Chemistry I Laboratory 0R-3L-1C F,W,S Prereq: None; Coreq: CHEM 111
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM111 recitation.

CHEM 112 Chemistry Honors 4R-3L-5C F Prereq: Advanced placement
An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-3C W,S Prereq: CHEM 111 and CHEM 111L; Coreq: CHEM 113L
Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 113L General Chemistry II Laboratory 0R-3L-1C W,S Prereq: CHEM 111 and CHEM 111L; Coreq: CHEM 113
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 115 General Chemistry III 3R-3L-3C W,S Prereq: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 115L
Topics in this course include acid-base reactions, electrochemistry, and coordination chemistry.

CHEM 115L General Chemistry III Laboratory 0R-3L-1C W,S Prereq: CHEM 113 and CHEM 113L or CHEM 112; Coreq: CHEM 115
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 200 Career Preparation 1R-0L-1C W
This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with MA200, and SV200.

CHEM 225 Analytical Chemistry 3R-3L-3C F, S Prereq: CHEM 115 and CHEM 115L; Coreq: CHEM 225L
This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate

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- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 225L Analytical Chemistry Laboratory 0R-3L-1C F, S Prereq: CHEM 115 and CHEM 115L; Coreq: CHEM 225

This course represents the laboratory component of analytical chemistry. Practicums are part of the grade along with reports.

CHEM 251 Organic Chemistry I 3R-0L-3C F Pre: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 251L

An introduction to the classification of organic compounds, their structural features, including stereochemistry, and concepts related to reaction mechanisms and synthetic methods.

CHEM 251L Organic Chemistry I Laboratory 0R-3L-1C F Prereq: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 251

Organic Laboratory techniques are developed along with appropriate spectroscopic methods. Assessment is in part via practicums. Computational chemistry methods and green chemistry approaches are also introduced.

CHEM 252 Organic Chemistry II 3R-0L-3C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252L

Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis, and an introduction to the methods used to determine structure, including IR and NMR spectroscopy and mass spectrometry.

CHEM 252L Organic Chemistry II Laboratory 0R-3L-1C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252

A continuation of CHEM251L where additional, more complicated synthetic techniques and methods along with additional spectroscopic techniques are introduced. Assessment is in part via practicums.

CHEM 253 Organic Chemistry III 3R-0L-3C S Prereq: CHEM 252 and CHEM 252L; Coreq: CHEM 253L

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 253L Organic Chemistry III Laboratory 0R-4L-1C S Prereq: CHEM 252 and CHEM 252L; Coreq: CHEM 253

Project based laboratory where techniques and skills developed in the previous organic laboratories are applied to more open-ended problems.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Prereq: CHEM 113 and CHEM 113L

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with BIO264.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Prereq: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Prereq: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research performed under the direction of a faculty member selected by mutual agreement. This course is designed for research performed before taking CHEM291. Students may register for 1 to 2 credit hours per quarter.

CHEM 291 Introduction to Chemical Research 2R-4L-3C W Prereq: CHEM 113/113L, or 112

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members and be required to attend all seminars during the quarter.

CHEM 304 Glassblowing 1R-3L-1C S Prereq: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Prereq: CHEM 225 and CHEM 225L

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Prereq: CHEM 225 and CHEM 225L

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Prereq: CHEM 252

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Prereq: CHEM 330 and BIO 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C W, S Prereq: CHE 303, CHE 304, and CHEM 115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Prereq: CHEM 115, CHEM 115L, MA212 and MA 381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Prereq: CHEM 111, CHEM 111L, MA 212, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 371 Environmental Analytical Chemistry 3R-4L-4C F Prereq: CHEM 251 and CHEM 251L (or concurrent enrollment), and CHEM 225 and CHEM 225L and CHEM 264

This course is a laboratory-driven course where processes involved in performing environmental analytical chemistry are addressed. The focus of this course is on the chemical principles, analytical theory, instrumentation, and methods employed to quantitatively and qualitatively analyze pollutants in soil, water, biological tissues, and the atmosphere. Several techniques will be included in the course: sampling (obtaining a representative sample of complex system); sample preparation (extraction, clean-up, pre-concentration, derivitization, digestion, etc.); data acquisition (The laboratory will include use of EPA/ASTM methods/protocols, method development, etc.); and data handling and analysis (statistics, signals, noise, etc.).

CHEM 391 Research Proposal 1R-0L-1C F,W,S Prereq: CHEM 291, RH 330; Coreq: CHEM 490

Students will take online lessons related to the generation and communication of research ideas culminating in the production of a research proposal. The research proposal will be written under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 395 Chemistry Seminar 0R-0L-0C F Prereq: None

Students will be required to attend and/or present research seminars, the number to be determined by the department. The students will register for the course in the fall of the third year and if all the requirements are met, the students will receive a grade of Satisfactory. Failure to meet the requirements during the fall quarter will result in No Grade and the student must complete the requirements by the end of the third year. If the requirements are not completed by the end of the third year, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 433 Biochemistry Laboratory 0R-3L-1C S Prereq: CHEM 330

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Prereq: CHEM252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Prereq: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 451 Organic Structure Determination 2R-8L-4C S Prereq: CHEM 253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Prereq: CHEM 251 or CE 564 or consent of instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F,W,S Prereq: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.

Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: Permission of instructor

Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Prereq: CHEM 291

Research performed under the direction of a faculty member selected by mutual agreement. Students may register for 1 to 3 credit hours per quarter.

CHEM 491 Research Thesis 1R-0L-1C F,W,S Prereq: CHEM 490

Students will publish a thesis on their undergraduate research. The thesis will be written under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 495 Chemistry Seminar 0R-0L-0C F Prereq: None

Students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 496 Chemistry Seminar 0R-0L-0C W Prereq: None

Students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 497 Research Presentation 1R-0L-1C F W S Prereq: CHEM 490

Students will deliver a professional seminar on their undergraduate research. A student must have at least three credit hours of CHEM490. The seminar will be prepared under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 530 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules. Students enrolled in CHEM 530 must complete a project not covered in CHEM 430. A student may not receive credit for both CHEM 430 and CHEM 530.

CHEM 531 Biochemical Instrumentation 3R-4L-4C Prereq: BIO 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 532 Biochemical Pharmacology 4R-0L-4C Prereq: CHEM 330

Topics include medicinal chemistry and molecular pharmacology. The topics will also include a survey of potential drug targets, the molecular interactions between drugs and their targets, the drug discovery and development process and case studies of drugs treating diseases such as cancer, bacterial and viral infection, and neurological disorders.

CHEM 545 Organometallic Chemistry 4R-0L-4C Prereq: CHEM 115, CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 552 Synthetic Organic Chemistry 4R-0L-4C Prereq: CHEM 253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 554 Theoretical Organic Chemistry 4R-0L-4C Prereq: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 555 Natural Products 4R-0L-4C Prereq: CHEM 253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 557 Synthetic Polymer Chemistry 4R-0L-4C Prereq: CHEM 252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 561 Advanced Physical Chemistry 4R-0L-4C Prereq: CHEM 363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 562 Physical Polymer Chemistry 4R-0L-4C Prereq: CHEM 361 or CHE 303

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 570 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses. If cross-listed with CHEM470, students in CHEM570 will need to complete an additional project.

CHEM 595 Chemistry Seminar 0R-0L-0C F Prereq: None

Chemistry graduate students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 596 Chemistry Seminar 0R-0L-0C W Prereq: None

Chemistry graduate students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 597 Chemistry Seminar 0R-0L-0C S Prereq: None

Chemistry graduate students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.

CHEM CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Civil Engineering

Professors Aidoo, Chapman, Hanson, Kershaw, Lovell, Marincel Payne, McKinney, Mueller Price, Robinson, and Sutterer.

CE 101 Engineering Surveying 0R-6L2C F Prereq: None

Covers basic principles and practices of surveying. Measurement through the application of surveying techniques; theory of errors and their analysis; concepts of horizontal, vertical, and angular measurement; coordinate systems; basic surveying operations and computations; reading and interpretation of building, highway, and/or bridge plans; traverse computations; applications to construction and design.

CE 111 Geographical Information Systems 2R-0L-2C W Prereq: None

The course covers introductory concepts of geographical information systems and related technologies. Topics covered will relate to the use, collection, creation, and analysis of spatial data in applying GIS and related technologies to civil engineering projects.

CE 205 Thermodynamics 4R-0L-4C F Prereq: MA 112

Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

CE 250 Sustainable Civil Engineering Design 2R-0L-2C W Prereq: EM 103

An introduction to sustainable design of civil engineering systems. Includes treatment of current issues as they relate to design and construction for economic, environmental and social aspects of civil engineering.

CE 303 Engineering Economy 4R-0L-4C W Prereq: None

Emphasizes time value of money and factors related thereto. Familiarizes students with concepts of annual cost, present worth, and minimum rate of return as tools for consideration of economic factors pertinent to the selection of alternate solutions to engineering problems.

CE 310 Computer Applications in Civil Engineering 2R-0L-2C S Prereq: CE371 and CE432

Students develop solutions to a variety of civil engineering problems using application programs such as Mathcad, Excel, and Matlab. Emphasis is made on problem solving approach and structured programming with software tools useful to civil engineering computation and design.

CE 320 Civil Engineering Materials 3R-3L-4C S

A study of the origin, nature, performance and selection criteria of various basic materials used in the practice of civil engineering. These include aggregates, portland cement, concrete, and bituminous materials. Emphasis will be placed on standard methods of testing and characterization as related to the mechanical behavior of materials.

CE 321 Structural Mechanics I 4R-0L-4C F Prereq: EM 203

Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Prereq: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Prereq: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE380 Introduction to Transportation Engineering 4R-0L-4C S Coreq: MA223, CE320

Study of transportation functions and transportation systems; measuring and estimating demand; characteristics of transportation modes, interactions between modes, and mode interfaces; social, environmental, technological, economic, and public policy impacts; techniques of transportation system planning, design, and operation, with an emphasis on highway geometric design.

CE 400 Career Preparation Seminar 1R-0L-0C S Prereq: CE 488

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Prereq: CE 321

Hand methods for structural analysis of indeterminate structures: approximating drift of frames and solid walls, force method, moment distribution method, distribution of shear when there is a rigid diaphragm, and in-plane diaphragm forces.

CE 431 Structural Design in Steel I 3R-0L-3C S Prereq: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Prereq: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 436 Foundation Engineering 4R-0L-4C F Prereq: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Prereq: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C W Prereq: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 445 Construction Methods and Equipment 4R-0L-4C F Prereq: Senior class standing and consent of instructor

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Prereq: CE 321 and CE471

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will look at major environmental regulations and sustainability assessment tools. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Prereq: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air

quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Coreq: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 463 Unit Operations in Environmental Engineering 4R-0L-4C F Prereq: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 471 Water Resources Engineering 4R-0L-4C W Prereq: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Geometric Design of Highways and Streets 4R-0L-4C W Pre: CE101 & CE380

Highway planning and design with evaluation of multiple alignment alternatives; geometric design of highways: horizontal and vertical alignment, cross-sectional design; intersection design; earthwork measurements and quantities; reverse curve design; legal aspects of transportation engineering; proper use of the American Association of State Highway and Transportation Officials (AASHTO) design guidelines.

CE 481 Traffic Analysis and Design 4R-0L-4C F Pre: CE380

Study of fundamentals of traffic engineering; components of the traffic system; intersection types and design elements; basic variables of the traffic system (flow, capacity, level of service, delay); design and analysis of traffic signals and intersections; traffic control and traffic impact analysis; safety performance and traffic crash analysis; use of the Highway Capacity Manual and traffic analysis software.

CE 482 Urban Transportation Planning 4R-0L-4C F or W Pre: CE380

Applies general principles of planning, evaluation, selection, adoption, financing, and implementation of alternative urban transportation systems to urban and regional planning; formulation of community goals and objectives, inventory of existing conditions; transportation modeling-trip generation, distribution, modal choice, assignment, technological characteristics and operation of modern transit and other movement systems.

CE 483 Railroad Engineering 4R-0L-4C S Pre: Junior standing or consent of instructor

Provides an overview of rail transportation: history, organizations, economics, safety, freight operations, track-train dynamics, signals and communications, motive power and equipment, track components, construction and maintenance. The basic objective of the course is to gain an understanding of railroads as a transportation industry that merges a number of engineering fields as well as other disciplines that contribute to the success of a complex, growth- oriented industry.

CE 486 Civil Engineering Design & Synthesis I 1R-3L-2C F Prereq: RH 330, CE 460; Coreq: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be initiated by small teams of students to implement principles used in planning, design, and synthesis. Learning objectives include contracting, concept development, concept feasibility, planning and scheduling design work, data collection for subsequent design.

CE 487x Technical System Design & Synthesis 2R-2L-2C W Prereq: CE486; Coeq: CE 488

Technical system design of interdisciplinary elements of civil engineering projects submitted by corporate and governmental sponsors will be completed by individual team members to fulfill the needs of a team project initiated with CE486 and continuing in CE488. The "x" will be used to identify subdiscipline designation (c = general civil design, e= environmental, g = geotechnical, s = structural, t = transportation, w = water resources).

CE 488 Civil Engineering Design & Synthesis II 1R-2L- 2C W Prereq: CE486; Coreq: CE 487

Project management by small teams for civil engineering projects submitted by corporate and governmental sponsors will continue. Learning objectives include coordinate of major design work in subdisciplines, progress reporting to the client, critical path model management to keep the project on schedule to fulfill the needs of a team project initiated with CE486 and continuing in CE487.

CE 489 Civil Engineering Design & Synthesis III 1R-3L-2C S Prereq: CE 487, CE488

Civil engineering projects submitted by corporate and governmental sponsors will be completed. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. Learning objectives include construction planning and cost, final reporting, and public presentation of findings.

CE 490 Directed Studies 1-4C Arranged. F,W,S Prereq: Approval of department head, adviser, and

course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

CE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

CE 520 Structural Engineering Practicum 0R-12L-4C Prereq: Grad or consent of instructor

Structural engineering practicum approved by the department.

CE 521 Matrix Methods for Structural Analysis 4R-0L-4C F Prereq: CE 321

Derivation of the direct stiffness method for truss and frame elements. Derivation of the finite element method for 2D plate elements. Requires development of computer programs to implement the direct stiffness method.

CE 522 Structural Dynamics 4R-0L-4C W Pre: Grad or consent of instructor Co-Req: CE 521

Analysis and behavior of structural members and systems subject to dynamic loads including basic theory for single-degree-of-freedom and multi-degree-of-freedom analytical models of civil engineering structures; seismic hazard analysis and methods of analysis for seismic loads; response spectra; time history; and linear and nonlinear methods.

CE 523 Advanced Solid Mechanics 4R-0L-4C W Prereq: Grad or consent of instructor

The fundamentals of elasticity are introduced and related to various problems such as beams on elastic foundations, unsymmetrical bending, torsion of thin walled members, and curved beams. Introduction to the analysis and modeling techniques for existing and repaired structures. Design of retrofit measures for a variety of structures using advanced composite materials.

CE 524 Building Design 4R-0L-4C S Prereq: Grad or consent of instructor and CE421

Advanced structural analysis and design concepts for buildings: material nonlinearity, plastic design, pushover analysis, bracing, floor vibrations. Course culminates in a design project.

CE 525 Bridge Engineering 4R-0L-4C S Prereq: CE 421, CE 431, CE 432

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Introduces concepts of bridge engineering by providing the students with the necessary knowledge and skills to apply the AASHTO LRFD specifications for the analysis and design of highway and bridge superstructure components.

CE 530 Structural Design in Timber 4R-0L-4C On Demand Prereq: Senior class standing or consent of instructor

Presents the analysis and design of structures constructed of timber.

CE 532 Structural Design in Concrete II 3R-3L-4C F Prereq: CE 432

Advanced topics in reinforced concrete analysis and design such as serviceability, slender columns, two-way slabs, and strut-and-tie modeling.

CE 533 Connections and Detailing 4R-0L-4C S Prereq: CE 431 and CE 432

Analysis and design of structural systems with emphasis on detailing requirements; behavior of bolted and welded connections, including gusset plates, moment-resistant connections, and simple connections; design and analysis of base plate and anchoring systems; and an introduction to seismic detailing requirements.

CE 534 Structural Design in Masonry 4R-0L-4C On Demand Prereq: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C F Prereq: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Prereq: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 537 Retaining Structure Design 4R-0L-4C W Prereq: CE 336, CE 432

Covers the determination of earth pressures, selection of appropriate retaining wall types, and design of commonly used retaining structures. Includes both external (geotechnical) and internal (structural) analysis.

CE 561 Air Pollution 4R-0L-4C W Prereq: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Advanced Wastewater Treatment 4R-0L-4C Prereq: CE 463

Covers the theory, design and analysis of biological processes for the treatment of wastewater. Treatment processes include suspended and attached growth processes, aerobic and anaerobic processes, biological nutrient removal, aeration and gas transfer, and biosolids processing.

CE563 Advanced Water Treatment 4R-0L-4C Prereq: CE 463

Covers the theory, design and analysis of physical and chemical processes for the treatment of drinking water. Treatment processes include coagulation and flocculation, gravity separation, granular and membrane filtration, disinfection, air stripping, adsorption, ion exchange, and disinfection.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Prereq: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Prereq: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Prereq: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Prereq: CE 471

Watershed planning and stormwater management strategies are examined using computer simulation models. With an emphasis on conceptual foundation, students will be introduced to some of the most widely used models in the fields of hydrology and stormwater quantity management. Topics examined include watershed loss, transform, and routing methods, as well as model configuration, calibration, and evaluation.

CE 568 Surface Water Quality Modeling 4R-0L-4C S Prereq: CE 460 or consent of instructor

Covers the mathematical analysis of transport and fate of pollutants in natural surface waters and their impact on water quality using analytical and numerical models. Includes one- and two-dimensional steady-state and transient models. Pollutants examined include oxygen-demanding organics, nutrients and toxic compounds.

CE 569 Treatability Studies 2R-6L-4C On Demand Prereq: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 570 Modeling Open Channel Hydraulics 4R-0L-4C W Prereq: CE 371

Presents steady and unsteady flow problems in open channels and pipes, dealing with mechanics of flow over rigid and mobile boundaries. Covers analysis of river dynamics and hydraulic principles in stormwater conveyance through numerical and computer modeling.

CE 571 Environmental River Mechanics 3R-3L-4C S Prereq: CE 371

Concepts of fluvial geomorphology and fluvial hydraulics are examined, including natural stream flow, sediment transport, and ecological processes in alluvial rivers. Students will apply these principles to solve common design problems of channel instability and rehabilitation of impaired streams. Students will visit local streams to perform field data collection of channel geometry, bed and bank material, and water quality.

CE 573 Groundwater Analysis 4R-0L-4C Prereq: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and

unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Prereq: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Prereq: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Prereq: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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College & Life Skills

CLSK 100 College and Life Skills 1R-0L-1C F Prereq: None
This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

CLSK 121 College English 4R-OL-4C Prereq: Consent of Instructor
Focuses on understanding the basic patterns and conventions of writing, enhancing reading skills and written comprehension, and improving verbal communication and oral comprehension. This course is intended for students for whom English is a second language. Students required to take CLSK121 must successfully complete the course prior to taking RH131.

CLSK 122 English Language and Culture in Academic Texts 3R-3L-4C Prereq: Consent of instructor required
Reviews English grammar and introduces and develops deeper understanding of academic vocabulary. Familiarizes students with essential essay structures in academia. Introduces academic readings in select topics of academic concern in American socio-culture. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 123 English Language in Academic Research and Composition 3R-3L-4C Prereq: Consent of instructor required
Introduces students to formal research and composition of research papers. Strengthen students' formal research and writing skills for research papers. Guides students through readings in academic journals and articles. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 124 English Language and Culture in Academic Speech, Presentation, and Argumentation 3R-3L-4C Prereq: Consent of instructor required
Emphasizes fluency in spoken English. Rehearses academic vocabulary. Prepares students for academic presentations including technology. Develops students' academic listening and note-taking skills focusing on topics of American socio-cultural study. Introduces students to Socratic discussion and argumentation. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 125 English Rhetoric and Culture in Academia 3R-3L-4C Prereq: Consent of instructor required
Prepares students for full-length lectures in courses related to their majors, focusing on oral rhetoric devices. The course does not satisfy any Rose-Hulman degree requirement.

- Air Force ROTC (Military)
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- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

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Course Descriptions

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Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Computer Science & Software Engineering

Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic, ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control.

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prereq: CSSE220 or CSSE221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE 280 Introduction to Web Programming 3R-3L-4C W Prereq: CSSE220 or CSSE221

Introduction to the client-side and server-side mechanisms for creating dynamic web pages with persistent data storage. Browser-webserver interaction via HTTP. Static web page creation using HTML5 and CSS3. Client-side programming using JavaScript, DOM, JSON. Server-side programming and data storage using PHP and MySQL. Asynchronous client-server communication using AJAX and extensions of JavaScript. Session maintenance using cookies. Security considerations. This course provides breadth of knowledge of many tools/technologies rather than deep knowledge of any particular tool/language. No previous experience with web page creation is required.

CSSE 290 Special Topics in Computer Science 1 - 4C Arranged Prereq: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prereq: CSSE230

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W,S Prereq: CSSE220 or CSSE221, and CSSE132 or CSSE232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prereq: MA275 and CSSE230 (or concurrent enrollment in CSSE230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prereq: CSSE220 or CSSE221, and MA212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 352 Computer Game Development 4R-0L-4C Prereq: CSSE230

An introduction to designing and developing computer games. Topics include game genres, game design, sprites, game physics, collisions, characters, scripting, graphics, and sound. Students will design and implement

their own game using an available game engine.

CSSE 371 Software Requirements Engineering 3R-3L-4C F Prereq: CSSE230, RH330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requ: CSSE371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict management. Professional issues including career planning, lifelong learning, software engineering ethics, and the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prereq: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Design 3R-3L-4C W Prereq: CSSE371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 3R-3L-4C S Prereq: CSSE374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prereq: CSSE230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 400 CSSE Seminar 4R-0L-4C Prereq: ICS major

This course presents an overview of current application areas within computer science and software engineering through the use of practical case studies. Students will undertake their own preparation of one or more case studies and present their results. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prereq: CSSE332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prereq: CSSE304

A survey of some current and emerging programming languages, focusing on unique language paradigms-ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prereq: CSSE232, CSSE304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prereq: CSSE230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a

textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prereq: CSSE220 or CSSE221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 435 Robotics Engineering 3R-3L-4C S Prereq: ME 430 or ECE 230

Interdisciplinary course in robotics focusing on communication, software development, kinematics, robot GUI design, sensing, control, and system integration. Labs in the course cover MATLAB GUI development with GUIDE, Denavit-Hartenberg parameters, Arduino programming, Arduino to Android communication, Android app development, and OpenCV4Android image recognition. Students in the course will program an Android + Arduino, 6-wheeled mobile robot with 5 DOF servo arm to participate in an outdoor GPS robotics challenge. Cross-listed with ME 435.

CSSE 433 Advanced Database Systems 4R-0L-4C S Prereq: CSSE333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prereq: CSSE332 and MA275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 443 Distributed Systems & IT Security 3R-3L-4C Prereq: ICS major

Building complex distributed information systems requires a systematic approach. This course covers the analysis of existing distributed information systems and provides the ability to model simple new distributed applications with special attention to the trustworthiness, reliability and security of information systems. Topics covered include the main architectural models of distributed systems, describing simple distributed applications according to architecture and function, defining simple communication protocols, the benefits of using middleware, the risks of using distributed systems, and safety measures. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 444 Real-time Systems 3R-3L-4C Prereq: ICS major

Students will learn the features and specifications of real-time systems. Topics covered include real-time operating systems and programming languages, design patterns for real-time systems, scheduling, synchronization, hybrid task sets, and applications of real-time systems. This course is taught as part of the International Computer Science dual degree program at Hochschule Ulm, Germany.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prereq: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence R-0L-4C Arr Prereq: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prereq: CSSE220 or CSSE221, and MA212 (MA371 or MA373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prereq: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability

distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prereq: CSSE230 and MA375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 477 Software Architecture 4R-0L-4C F Prereq: CSSE374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 479 Cryptography 4R-0L-4C S Prereq: CSSE220 or CSSE221, and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 480 Web App Frameworks with AppEngine 3R-3L-4C F Prereq: CSSE230 and CSSE280

Development of desktop and mobile web applications using Google AppEngine. Additional web frameworks include Jinja2, Cloud Datastore, jQuery, Bootstrap, DataTables, Cloud Storage, Cloud Endpoints, and AngularJS. Topics covered using these frameworks include the HTML, CSS, and JavaScript development of client side web apps, sending and receiving REST requests, designing Datastore models, HTML5 and CSS3 features including CSS animations, file storage, Ajax requests, and user OAuth. Emphasis is on hands-on use of these frameworks in web application development. Includes a substantial team project (UI mockups, user stories, development, testing, and presentation).

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prereq: CSSE230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE 483 Android Application Development 4R-0L-4C Prereq: CSSE230

An introduction to programming mobile applications using the Android stack. Topics include the activity lifecycle, resources, layouts, intents for multiple activities, menus, fragments and dialogs, adapters, data persistence via shared preferences, SQLite, and web backends. Emphasis is on hands-on use of these components in application development. Includes a substantial team project (UI mockups, user stories, UML design, development, testing, and presentation).

CSSE 484 iOS Application Development 3R-3L-4C W Prereq: CSSE230

An introduction to programming mobile applications using the iOS stack. Topics include using X-Code for Swift and Objective-C app development, UI components, Storyboards, view controller actions and outlets, table views, navigation controllers, Core Data, and APIs for backend communication. Emphasis is on hands-on use of these components in application development. Includes a substantial team project (UI mockups, user stories, development, testing, and presentation).

CSSE 487 Senior Research Project I 4C Arranged Prereq: RH330 and senior standing

CSSE 488 Senior Research Project II 4C Arranged Prereq: CSSE487

CSSE 489 Senior Research Project III 4C Arranged Prereq: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arranged Prereq: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arranged Prereq: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arranged Prereq: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arranged Prereq: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arranged Prerequisite: RH330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arranged Prerequisite: CSSE494

CSSE 496 Senior Thesis III 4C Arranged Prerequisite: CSSE495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Capstone Project I 4C F Prerequisite: CSSE371 and senior standing

CSSE 498 Senior Capstone Project II 4C W Prerequisite: CSSE 374 and CSSE497

CSSE 499 Senior Capstone Project III 4C S Prerequisite: CSSE498

For a capstone experience, students work on a team to complete a three-term software engineering project for an approved client. Students choose from two approaches to complete their capstone: 1) Develop a substantive software product, using defensible software processes. The teams focus on delivering key software development, administrative, and user artifacts to the client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure. 2) Investigate a substantive software product or engineering process problem, using a defensible and documented research approach. Tasks include problem analysis, developing alternative solutions, evaluating the solutions via prototyping and iterative processes of investigation, comparing the potential solutions, recording the investigation experience in a research report, and delivering the research artifacts to the client.

CSSE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Course Descriptions

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Minors	Graduate Studies

CATALOG HOME

Electrical & Computer Engineering

Sensors and actuators. Input and output devices. Microcontroller architecture. Standard communications protocols. Interrupt generation and processing. Data representation and storage. Memory management. The C programming language and programming styles. Integral laboratory and a term project.

Physics

ECE 233 Introduction to Digital Systems 3R-3L-4C F, W Pre: CSSE 120

Number systems. Boolean algebra. Combinational logic analysis and design. Logic minimization. Static hazards. Flip-flops, registers, and counters. Sequential logic analysis and design. Finite state machines. Synchronous circuit timing analysis. HDL design and synthesis techniques. Design verification through logic simulation and FPGA implementation. Integral laboratory.

ECE 250 Electronic Device Modeling 3R-3L-4C S, F Pre: ECE204 or ECE205. For non-EE and non-Cpe majors: ES203 with B or better

Introduction to two and three terminal semiconductor devices with a focus on circuit applications. Device characteristics and modeling, circuit application analysis, design, testing, and simulation. Large and small-signal models are introduced in conjunction with circuit analysis and testing. Introduction to wave shaping circuits and to digital and analog applications. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Prereq: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,S Prereq: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Integral laboratory.

ECE 312 Communication Networks 4R-0L-4C W Prereq: MA381, CSSE120

Layered architectures. Circuit and packet switching. The ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Queuing theory. Reliable message transport, internetworking.

ECE 320 Linear Control Systems 3R-3L-4C F,W Prereq: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C W,S Prereq: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C S Prereq: CSSE 232

Pipelining, memory hierarchy, peripherals, parallel processing, cost-performance tradeoffs, and a review of new topics in the areas of computer architecture or parallel processing. Computer use, memos, and discussion of current events.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Prereq: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Prereq: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 343 High-Speed Digital Design 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Signal path modeling through connecting lengths of transmission lines with lumped element models of

discontinuities. Circuit parameters from geometries and material properties for resistance, capacitance, inductance and transmission line segments. Lossless and lossy transmission line circuit modeling. High-frequency and high-speed behavior of passive components. Frequency spectrum of digital signals. Digital device driver and receiver modeling. Transmission line impedance discontinuity and termination techniques. Electric and magnetic field coupling mechanisms for capacitive and inductive crosstalk. Ground noise, power plane noise and resonance. Signal and power integrity issues in high-speed digital systems at both the printed-circuit board and chip levels.

ECE 351 Analog Electronics 3R-3L-4C F,W Prereq: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal properties of op-amps. Integral laboratory.

ECE 362 Principles of Design 3R-0L-3C F,S Prereq: ECE204, ECE205, ECE230, ECE233, ECE250 and ECE300

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3R-1L-4C F,S Prereq: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, and wind technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C W,S Prereq: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C F,W Prereq: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE 412 Software Defined Radio 3R-3L-4C S Prereq: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front end, and clock-jitter of the A/D. In the integral laboratory students will use LabVIEW to create a complete digital radio using the NI USRP 2920 platform.

ECE 414 Wireless Systems 4R-0L-4C W Prereq: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Prereq: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with CHE 405, EP 410, and ME 416.

ECE 418 Fiber Optic Systems 4R-0L-4C S Prereq: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing systems, and optical networks. Topics include basic architectures, component overview, system design, and expected degradations along with mitigation techniques. An oral presentation of a technical paper is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Prereq: ECE 320 or ME 406

Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prereq: CSSE 120 and (ECE 320 or ME 406 or BE 350 or CHE 440)

This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Prereq: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Prereq: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Prereq: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, W Prereq: ECE362

For EE: Prereq or concurrent registration in the remainder of ECE230, ECE310, ECE320, ECE341, ECE351, ECE370 or ECE371, ECE380

For CPE: Prereq or concurrent registration in the remainder of CSSE332 or CSSE230, ECE250, ECE230, ECE312, ECE332, ECE343, ECE380 or ECE320

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W, S Prereq: ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W,S Prereq: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Prereq: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Prereq: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Prereq: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Prereq: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/OE 437 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Prereq: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Prereq: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Prereq: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Prereq: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Prereq: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor

Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ME 519, EP 511, and CHE 519.

ECE530 Advanced Microcomputers 3R-3L-4C S Prereq: Graduate standing and ECE 331 or ECE 230; or ECE 331 or ECE 230 with a grade of B or better; or consent of instructor

32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software debugging tools. Integral laboratory.

ECE 531 Digital Test and Product Engineering 3R-3L-4C S Pre: Graduate standing and ECE230 Intro to Embedded Systems, ECE233 Intro to Digital Systems and ECE250 Electronic Device Modeling; or ECE230, ECE233, and ECE250 with grades of B or better in all three courses; or consent of instructor.

Industrial testing techniques for microcontrollers and other digital integrated circuits. Includes common digital system fault modeling, test generation, and design for testability in addition to memory testing strategies. Integral labs using an industrial grade automatic test environment (ATE).

ECE534 Advanced Signal and Power Integrity 4R-0L-4C W Prereq: Graduate Standing and ECE341, ECE342, or ECE343; or ECE341, ECE342, or ECE343 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal and power integrity modeling and measurement in high-speed digital systems at IC, PCB, and chassis levels. High-frequency behavior of passive components and packages. Behavior and SPICE models of drivers and receivers. Lossy transmission lines and discontinuity characterization. Mixedmode s-parameters and other network parameters. Frequency and time-domain modeling of capacitive and inductive crosstalk. Differential signaling techniques; timing conventions. Synchronization. Signal equalization. Power plane noise and resonance. High-speed PCB design guidelines. Measurement techniques including time-domain reflectometry, vector network analyzer and impedance analyzer. PCB simulation. Full-wave simulations.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Prereq: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of instructor

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C W Prereq: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Wave-guiding structures, microwave network analysis, scattering parameters, Z, Y and ABCD parameters, passive devices and components, design, fabrication, simulation and measurement of microwave devices and components, matching strategies, multi-conductor transmission lines and crosstalk.

ECE542 Advanced Electromagnetics 4R-0L-4C F Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, EM field theorems, potential functions, power and energy, material properties, wave propagation, reflection and transmission, radiation, scattering, Green's functions, metamaterials and metamaterial-inspired structures, modeling & simulation, measurement technique.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Prereq: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Prereq: Graduate standing and ECE351 and ECE380, or ECE351 and ECE380 with a grade of B or better in both courses, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier

design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C S Prereq: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C S Prereq: Graduate standing and ECE351, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Analog signal processing techniques using operational amplifiers. A/D and D/A converters. Protection from electric shock. Measurement of biological potential waveforms (ECG, EMG, EEG, ENG, EOG, ERG). Ultrasound techniques and instrumentation. X-ray CAT techniques. No laboratory, but many in-class demonstrations and emphasis on circuit simulation.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C S Prereq: Graduate standing and ECE 351; or ECE 351 with a grade of B or better; or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE 557 Analog Test and Product Engineering 3R-3L-4C F Prereq: Graduate standing and ECE 300 and ECE 351; or ECE 300 and ECE351 with grades of B or better in both courses; or consent of instructor

Fundamental skills necessary to be an industrial integrated circuit test engineer or product engineer. Includes the economics associated with testing, impact of fabrication variation on devices, instrumentation associated with industrial testing, turning a data sheet into a test plan, industrial testing techniques for analog circuits, trade-offs between test time and test accuracy, statistical analysis of the data and statistical process control, the use of device interface boards necessary to control device loading for different tests. Integral labs with an industrial grade automatic tester (ATE).

ECE 558 Mixed-Signal Test and Product Engineering 3R-3L-4C W Pre: Graduate standing and ECE300 Continuous Time Signals and Systems, ECE233 Intro to Digital Systems, and ECE351 Analog Electronics; or ECE300, ECE233, and ECE351 with grades of B or better in all three courses; or consent of instructor.

Industrial testing techniques for AC and DC tests of mixed-signal integrated circuits using an automatic test environment (ATE). Includes the structure and operation of comparators and standard data converters (DACs, ADCs), common data converter datasheet specifications, impact of data converter design on testing strategies, and statistical analysis of accuracy-time trade-offs. Integral labs using an industrial grade ATE.

ECE580 Digital Signal Processing 4R-0L-4C W Prereq: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Prereq: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 120 or ME 123 and SR standing or GR standing.

Introduction to image segmentation and recognition. Use of neural networks, fuzzy logic and morphological methods for feature extraction. Advanced segmentation, detection, recognition and interpretation. Relevant laboratory experiments and required project. Cross-listed with OE 537.

ECE 583 Pattern Recognition 3R-3L-4C S Prereq: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 584 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and ECE300, or ECE300 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as BE541.

ECE 597 Special Topics in Electrical Engineering 4C **Prereq: Consent of instructor**
Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C **Arranged**
Thesis topic selected in consultation with adviser. Graduate students only.



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Engineering Management

Professors Andrijcic, Downing, Hamasha, James, Kline, Schumacher and Stamper

EMGT ESC - Escalate Program Participant - 0C

Students participating in the Escalate entrepreneurship program will be enrolled in this zero credit section each quarter. The course will be graded S or U. A grade of S will be given for completing the required Escalate courses, attending required professional development activities, and completing required project activities. Only students in the Escalate cohort may enroll in this section.

EMGT100 Introduction to Entrepreneurship 4R-0L-4C

This course provides an overview of the principles of entrepreneurship and becoming an entrepreneur in today's society. Topics include opportunity identification, market investigation, product development, developing marketing and business plans, and understanding business, financial, and legal matters related to venture creation. Concepts from the lean startup and canvas tools will be applied.

EMGT152 Economic Thinking for Entrepreneurs 1R-0L-1C Corequ: SV151 or consent of instructor
During this course students discuss the economic implications of entrepreneurial actions.

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4CPre: Junior, Senior, or consent of instructor
Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC Pre: MG 461 or consent of instructor
Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC Pre: MG 462 or consent of instructor

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT511 Graduate Seminar I 1R-0L-1C F

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT512 Graduate Seminar II 1R-0L-1C W

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT513 Graduate Seminar III 1R-0L-1C S

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT514 Graduate Seminar IV 1R-0L-1C Summer

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT520 Accounting for Technical Managers 4R-0L-4C Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership & Organizational Culture 4R-0L-4C Management

This course reviews the management literatures on leadership and organizational culture. It explores that interaction and the range of differences found in practice. Additional topics include: Organizational Change, Vision & Strategy, Business Ethics, and Senge's Learning Organization. Course activities include the 'Winning At Design Automation' simulation that demonstrates cultural issues surrounding rapid growth in a high tech, high commitment company, and The Ethics Challenge game. Students select a company as the topic of their term paper, describing its culture (Schein's approach) and a plan to promote change (Conger's Charismatic Leadership). Students make a 'call to action' speech to convey their leadership plan.

EMGT523 Marketing in New Product Development 4R-0L-4C Management

This course explores marketing concepts and marketing strategy within the context of new product development.

Topics addressed include: market research methods, market segmentation, product positioning (4 Ps), pricing strategies, alliances, elasticity, advertising & brands, and the champion role. Student projects define a new product idea, apply course concepts to the development of that idea (segmentation, pricing, etc.) and present their analysis to the class. The course includes the 'NPDCChallenge'simulation that demonstrates marketing issues an entrepreneur faces in developing a new product.

EMGT524 Production/Operations Management 4R-0L-4C Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-0L-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-0L-4C

This course introduces the concepts of innovation types (radical, incremental, disruptive, open), invention, and diffusion to identify patterns of technology change. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, Delphi, roadmapping, and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-0L-4C Technical or Management

This course presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, estimating, scheduling, Mythical Man Month, Critical Path & Critical Chain, task partitioning & communication, rework, and negotiation. Students apply these concepts in writing case analyses. Typical problems and success factors are discussed in relation to project management choices. Special issues encountered in virtual teams are discussed.

EMGT529 Organizational Behavior 4R-0L-4C

This course will introduce students to principles and theories related to management and organizational behavior. The goal is to transfer or develop knowledge and skills for high performance in a complex technical business environment requiring engineers to make and communicate sound decisions, and react appropriately to unanticipated events. The concepts and techniques for maximizing the effectiveness of engineers in the achievement of organizational and project goals are also emphasized. Topics include power, teaming, motivation, selection, and development while understanding individual characteristics, attitudes, and behaviors. Additionally, we will examine how the use of Emotional Intelligence (EI) will be useful to the advancement of organizations that are culturally diverse.

EMGT531 Economics for Technical Managers 4R-0L-4C Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C Management

This course presents the Constructivist theory of communication and its application. The culture concept is applied at ethnic (~70%) organizational and interpersonal levels. The course balances theory and application and students write analysis of videos to apply course concepts. Students use Spradley's Ethnoscience approach to conduct interviews and write an ethnography for their term paper. The course helps students to better: develop interpersonal relations, improve their interviewing skills, analyze cultures, and understand diversity across ethnic & gender differences. Concepts include: Culture Shock, Empathy, The Social Construction of Reality, Non Verbal Communication, High & Low Context cultures, M time & P time cultures.

**EMGT534 Management Science 4R-0L-4C F (even years) Prereq: Senior or graduate standing
Technical or Management**

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-0L-4C Management

This course samples the strategy literature and distinguishes economic and managerial (resource based view) perspectives. Strategy issues encountered in transnational management are addressed in cases. Scenario planning is described. Trends and implications of globalization are explored (off shoring, 'rise of the rest', resource use & climate change, BOP, Business Model change) and the 'great recession' is discussed from a long wave perspective. Strategy implementation issues are addressed. Students develop strategies for an organization of their choice and evaluate those strategies using the 'Scenario to Strategies' approach in their term paper.

EMGT536 Leadership and Global Challenges 4R-0L-4C

This course examines the art of leadership and its development in our increasingly globalized society. In this course students will apply their general education and use their knowledge, experience, and perspectives learned in a variety of disciplines to investigate the nature and dynamics of leadership. Examining general theoretical approaches, with close attention to the unique challenges which globalization and cross-cultural interactions impose upon leaders, the class will work on three case studies. The first case study focuses on an individual in order to illustrate leadership development. The second will focus on a corporation in order to illustrate mutual influence of leaders, constituents, and organizations. The third will be about an event or a situation which exemplifies the challenges and creativity of leadership in global/transnational/multicultural operations.

EMGT540 Fundamentals of Engineering Management 4R-0L-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT 551 Intellectual Property for Engineers and Scientists 4R-0L-4C Technical or Management Elective

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-0L-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT562 Risk Analysis and Management 4R-0L-4C

This course will introduce students to principles and methods of risk analysis and risk management, as related to diverse engineering and socio-technical systems. Students will learn how to: identify, prioritize and quantify risks; perform qualitative and quantitative risk assessments and develop risk models; assess uncertainty; identify, evaluate, and prioritize risk management alternatives; and communicate risk to stakeholders. Through the use of varied example problems and case studies, students will develop an understanding of the appropriate use of risk analysis and management methods for engineering and policy decision making under uncertainty.

EMGT564 Systems Architecture 4R-0L-4C Prereq: Senior standing or consent of instructor

This class will introduce students to the art and science of systems architecting, where systems architecting refers to uncovering the fundamental structure of a system (functional, physical, logical, operational) defined in terms of system's elements, interfaces, processes, constraints, and behaviors that must operate under specific requirements and constraints. Focus will be placed on investigating the broader meaning of architectures, as they relate to organizations and businesses, in addition to engineered systems and products. Students will be introduced to heuristic and model-based approaches for systems architecting. Through case-studies and example problems in areas of production and manufacturing systems, intelligent transportation systems, social systems, and others, students will be able to apply the principles, processes and tools of systems architecting in order to structure and support the system development process of a balanced, well-integrated and socially and financially acceptable system.

EMGT567 Economic Analysis of Engineering Projects 4R-0L-4C Prereq: Senior standing or consent of instructor

This class will introduce students to critical principles of economic analysis of engineering projects. In particular, students will explore the process of making economic decisions under the influence of possibly uncertain future conditions and events. These economic decisions might involve investing in new facilities, improving existing production processes, or developing and marketing new products or services in the private and public sectors. Deterministic and multi-attribute evaluation approaches will be discussed. Students will be introduced to methodologies including capital budgeting, cost estimating, various alternative comparison methods, and life cycle costing. Additionally, students will be introduced to the concept of welfare economics through which they will explore economic impacts of infrastructure projects in the public sector. Emphasis will be placed on systems thinking and a systems approach to defining and solving economic problems.

EMGT581 Multi-objective Optimization 4R-0L-4C Prereq: Senior standing or consent of instructor

This course will consider how humans make optimal decisions in an uncertain environment, when they have to simultaneously satisfy multiple objectives/goals under limited resources. Specifically we will consider: how to structure multi-objective problems, different methods and theories of quantifying preferences over multiple objectives a priori or a posteriori, multi-objective optimization methods without preference specification, multi-attribute utility theory, value trade-offs, risk attitudes, and other topics like fuzzy methods. We will also consider the applications of these theories and methods to various problems, including managerial and operational business issues, public policy issues, development of new businesses, etc.

EMGT584 Systems Thinking and Evaluation 4R-0L-4C

This course will focus on applying systems thinking and methodologies, as well as parametric and nonparametric statistical methods to evaluate alternative system designs and design performance measures. Students will learn how to: identify and evaluate system goals, requirements and performance measures; design experiments to assess system performance; apply decision analysis techniques to diverse trade studies; and generate a business case for presenting technical analysis results.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization. Cross-listed with EMGT 486.

EMGT587 Systems Engineering 4R-0L-4C Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C Technical

Introduction to quality for the technical manager including management principles and technical methods.

Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Prereq: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Trustees
Parents

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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Mechanics

All courses in the engineering mechanics area are the responsibility of the Civil and Mechanical Engineering Departments.

EM 101 Statics 2R-0L-2C F Prereq: None
Covers static force analysis. Introduces scalars and vectors with applications to the study of forces, moments, and couples. Stresses free body diagrams with engineering examples.

EM 102 Graphical Communications for Civil Engineers 1R-2L-2C W Prereq: CE major only or consent of instructor
Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication. Focus on civil engineering applications.

EM 103 Introduction to Design 1R-3L-2C S Prereq: None
Introduces the engineering design process including problem definition, analysis, alternate solutions, specifications of final solution, and techniques of oral and written communications. Stresses the importance of teamwork through group design efforts.

EM 104 Graphical Communications 1R-2L-2C F Prereq: None
Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication.

EM 120 Engineering Statics 4R-0L-4C F,S Prereq: MA 111
Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, shear and bending moment diagrams, friction, and area moments of inertia. Emphasizes free-body diagrams.

EM 121 Statics and Mechanics of Materials I 4R-0L-4C F,W,S Prereq: MA 111
Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, and strength and elastic deflection of engineering materials due to loads applied axially. Emphasizes free-body diagrams.

EM 202 Dynamics 4R-0L-4C F Prereq: MA 112 and EM 120 or PH 111
Kinematics and kinetics of particles in space and rigid bodies in plane motion. Applications of the principles of Newton's laws, work-energy, impulse-momentum, and conservation laws to solutions of simple two-dimensional dynamics problems.

EM 203 Mechanics of Materials 4R-0L-4C F,W Prereq: EM 120
Strength and elastic deflection of engineering materials due to loads applied axially, in torsion, in bending, and in shear. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 204 Statics and Mechanics of Materials II 4R-0L-4C F,S Prereq: EM 121
Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 301 Fluid Mechanics 4R-0L-4C S Prereq: EM 202

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- Army ROTC (Military)
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- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

EM403 Advanced Mechanics of Materials 4R-0L-4C S Prereq: EM 203 or EM 204

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

EM 406 Vibration Analysis 4R-0L-4C F Prereq: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

UNDERGRADUATE-GRADUATE COURSES

EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Prereq: ME401 or consent of instructor

Course may be repeated for different topics in fluid mechanics.

EM 502 Advanced Dynamics 4R-0L-4C Prereq: ES 205

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

EM 503 Advanced Vibration Analysis 4R-0L-4C W Prereq: EM 406

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.

EM 505 Theory of Elasticity 4R-0L-4C Prereq: EM 203 or EM 204

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Prereq: EM 403 and MA 330

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher,Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W
Scaling laws in small systems; electronics and photonics devices and systems, basics of quantum and statistical mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, Nanophotonics in metals and semiconductors, surface plasmon resonance and applications, photonic bandgap crystals.

EP 290 Directed Study Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 330 Material Failure 3R-3L-4C W Prereq: PH112
Principles of material failure; appearance, physical cause and mathematical description with emphasis on the materials used for micro-scale devices and assemblies. Failure types considered include Rupture, Fatigue, Creep, Corrosion, Electromigration, Electrical Overstress, Electrical Discharge and Thermal. Experiments illustrate the failure type and the machines used to study them. These include Electron, Optical and X-ray microscopes, Spectroscopy and Tension machines. A brief description of the working of each machine will be given.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S
Scaling laws in small systems; mechanical, biological, fluidics, and thermal systems. Nanomaterials and nanofabrication. Nanomechanics: cantilever oscillation, atomic-force microscopy (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors. Nanoscale optics, Nanoscale heat: conduction, convection, and blackbody radiation. Basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise. Cross-listed with EP 506.

EP 407 Semiconductor Fabrication & Characterization 2R-6L-4C F Prereq: PH405 or JR/SR standing & consent of instructor
Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film

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- Chemical Engineering
- Chemistry and Biochemistry
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- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation.

EP 408 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410 or equivalent course

Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-listed with ECE 419, and CHE 419.

EP 415 Engineering Physics Design I 2R-6L-4C S Prereq: OE 280 or EP 280 & JR/SR standing Coreq: RH 330

Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with OE 415.

EP 416 Engineering Physics Design II 2R-6L-4C F Prereq: EP 415

Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with OE 416.

EP 417 Engineering Physics Design III 2R-6L-4C W Prereq: EP 416

Continuation of EP 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with OE 417.

EP 470 Special Topics in Engineering Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 406.

EP 507 Semiconductor Fabrication and Characterization 2R-6L-4C F Prereq: PH405 or consent of instructor

Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-

junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both EP 407 and EP 507.

EP 508 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.



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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Science

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 211 Differential Equations (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 212 Matrix Algebra & Systems of Differential Equations (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,

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Army ROTC (Military)
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Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,

- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,
- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Prereq: EM 121, MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better

Extend the conservation and accounting framework to examine fluid motion. Topics include dimensional analysis, pressure variation in both stationary and moving fluids, viscous effects including boundary layers, laminar and turbulent flow. Applications include lift and drag, pipe flow, compressible flow. Fundamental concepts are enriched by laboratory experiences.

ES 203 Electrical Systems 3R-3L-4C F,W,S Prereq: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better; ME 123 or BE 100 or CSSE 120 (or equivalent). Coreq: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Prereq: ES 203 with a grade of C or better, or ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Geology

GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Prereq: CHEM 111
Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.

- Air Force ROTC (Military)
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- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
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- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
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Prospective Students

Current Students

Faculty and Staff

Alumni and Friends

Industry Partners

Trustees

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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Mathematics

Professors Broughton, Bryari, Butske, Carlisle, N. Chenette, Eichholz, Evans, Finn, Goulet, Graves, Green, Grimaldi, Holden, A. Holder, L. Holder, Isaia, Langley, Leader, McSweeney, Panaggio, Rader, Reyes, Rickert, Selby, Shibberu, Tabing and Tarrant.

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Prereq: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.

A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen.

Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals).

Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

MA 111 Calculus I 5R-0L-5C F,W

Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

MA 112 Calculus II 5R-0L-5C F,W,S Prereq: MA111

Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

MA 113 Calculus III 5R-0L-5C F,W,S Prereq: MA112

Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

MA 190 Contemporary Mathematical Problems 2R-0L-2C S Co-requisite: MA113

A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and applications, famous problems, and outstanding problems of great significance.

MA 200 Career Preparation 1R-0L-1C W

This course is for mathematics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200 and PH200.

MA 211 Differential Equations 4R-0L-4C F,W, S Prereq: MA113

First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and

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Biomathematics

Chemical Engineering

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Civil Engineering

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Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

mathématiques

Mechanical Engineering

engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F,W,S Prereq: MA113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F,W,S Prereq: MA112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Prereq: MA112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Prereq: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W (odd years) Prereq: MA113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F,S Prereq: MA113, MA212

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F, W Prereq: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C F,S Prereq: MA211 and MA212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values

problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Prereq: MA211, MA212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA 342 Computational Modeling 4R-0L-4C S Prereq: MA212 and one of CHE310, CE310 ,MA332 or ME323

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 351-6 Problem Solving Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Prereq: MA275 and MA113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Prereq: MA212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Prereq: MA212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Prereq: MA212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Prereq: MA275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Prereq: MA275

An introduction to Group Theory. Topics include: matrix groups, groups of integers modulo a natural number, symmetric and dihedral groups, homomorphisms, subgroups, cosets, quotient groups and group actions. Applications, possibly including games and puzzles, cryptography, and coding theory. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Prereq: Consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F,W,S Prereq: MA113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment

generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C F Prereq: MA381

This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the entral Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Prereq: MA223 or MA382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Prereq: MA223 or MA382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 385

MA 386 Statistical Programming 4R-0L-4C Prereq: previous programming course and either MA223 or MA382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Prereq: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 390 Topics in the Mathematics of Engineering 1-2C Arranged Prereq: consent of instructor

A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

MA 421 Tensor Calculus and Riemannian Geometry 4R-0L-4C Arranged Prereq: MA330

An introduction to the calculus of tensor fields and the local geometry of manifolds. Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

MA 423 Topics in Geometry 4R-0L-4C Arranged Prereq: MA371 or MA373 or consent of instructor

An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C Arranged Prereq: Instructor permission

A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C Arranged Prereq: MA330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to “direct methods.” Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Prereq: MA212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C Arranged Prereq: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 435 Finite Difference Methods 4R-0L-4C W Prereq: MA332 or MA371 or MA373 or MA433

An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Prereq: MA330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green’s function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Prereq: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Prereq: MA212 and one of MA371 or MA373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development “from the ground up.”

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Prereq: MA223 or MA381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Prereq: MA375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C Arranged Prereq: Instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C Arranged Prereq: MA366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C Arranged Prereq: MA366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C Arranged Prereq: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Prereq: MA371 or MA373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Prereq: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C Arranged Prereq: MA375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Prereq: MA375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Prereq: MA375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C Arranged Prereq: MA 378 or MA375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Prereq: CSSE220 and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C Arranged Prereq: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Prereq: MA382, or MA381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Prereq: MA223 or MA382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Prereq: MA212 and either MA223 or MA382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Prereq: MA223 or MA382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics Variable credit Prereq: Consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Prereq: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Prereq: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F,W Prereq: MA492 or permission of the instructor

MA 494 Senior Project III 2C W,S Prereq: MA493

Either participation in a sponsored project or investigation of a problem with a substantial mathematical application, modeling and/or computational content. Students either work individually or in a team typically of 2 or 3, under the supervision of the faculty adviser (course instructor), interacting with the sponsor (if there is one). Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of the Senior Project must be completed in a form acceptable to the adviser and the sponsor if there is one. A submitted written report and public presentation to department are required

MA 495 Research Project in Mathematics Variable credit Prereq: Consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Prereq: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Prereq: MA496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Prereq: MA497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

MA CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Prereq: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C Arranged Pre: MA381

Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C Arranged Prereq: MA223 or MA381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Prereq: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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ME 123 Computer Programming 4R-0L-4C F,W,S Prereq: ME/PHOE major or permission of instructor
Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion, presentation software, and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S
Selected student design projects. May include testing and/or computer aided design.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Sophomore class standing
Selected student design projects. May include testing and/or computer aided design.

ME 301 Applications of Thermodynamics 4R-0L-4C F,W Prereq: ES 201 with a grade of C or better or CE205
Extend the conservation and accounting framework to examine energy-conversion systems. Topics include thermodynamic properties of pure substances, gas mixtures, exergy analyses, power and refrigeration cycles, psychrometric processes, combustion, and propulsion.

ME 302 Heat Transfer 4R-0L-4C S,F Prereq: MA 211 and ES 202 or CHE 301 or EM 301
Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Prereq: ES 202
Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Prereq: EM 104
This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Prereq: ME 328
An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Prereq: EM 103, ES 205, MA 223

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Numerical Methods in Engineering 1R-3L-2C W,S Prereq: ME 123, or CSSE 120, MA 212

Engineering problems often lead to analytically intractable equations. This course combines structured programming and applied numerical methods to obtain approximate engineering solutions. Strategies include root finding, numerical integration, finite difference, initial value and boundary value problems. Matlab is used as the programming language for solving iterative problems numerically.

ME 328 Materials Engineering 4R-0L-4C W Prereq: CHEM 111

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Prereq: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 397 Special Topics in Mechanical Engineering 4R-0L-4C

Topics of current interest in mechanical engineering at the 300-level.

ME 401 Foundations of Fluid Mechanics 3R-3L-4C Prereq: ES 202 or EM 301, MA 212

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

ME 402 Advanced Heat Transfer 4R-0L-4C Prereq: ME 302

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

ME 403 Kinematics of Machinery 4R-0L-4C Prereq: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

ME 405 Theoretical Aerodynamics 4R-0L-4C F Prereq: ES 202

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

ME 406 Control Systems 3R-3L-4C F Prereq: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Prereq: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are taken when available.

ME 408 Renewable Energy 4R-0L-4C Prereq: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic

energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C S Prereq: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Prereq: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Prereq: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Prereq: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 410, ECE 416, and CHE 405.

ME 417 Advanced Materials Engineering 4R-0L-4C Prereq: ME 328 and EM 203 or EM 204

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ECE 466, CHE 420, and CE 420.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Prereq: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Prereq: EM204

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Prereq: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Prereq: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation.

Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Prereq: ES 205 or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

ME 430 Mechatronic Systems 3R-3L-4C F,W Prereq: ME 323 or CSSE 220 or ECE 230

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

ME 435 Robotics Engineering 3R-3L-4C S Prereq: ME 430 or ECE 230

Interdisciplinary course in robotics focusing on communication, software development, kinematics, robot GUI design, sensing, control, and system integration. Labs in the course cover MATLAB GUI development with GUIDE, Denavit-Hartenberg parameters, Arduino programming, Arduino to Android communication, Android app development, and OpenCV4Android image recognition. Students in the course will program an Android + Arduino, 6-wheeled mobile robot with 5 DOF servo arm to participate in an outdoor GPS robotics challenge. Cross-listed with CSSE 435.

ME 447 Visualizing Data 4R 0L 4C. Prereq: Junior standing.

The course is about creating truthful and compelling data visuals. We study elements of statistical analysis, programming in R, human perception, graphic design, and visual rhetoric and ethics. After successfully completing this course, students should be able to design effective and truthful data displays, credibly explain their design rationale, produce publication quality visuals, and credibly critique a data display. Prior experience with R is not required.

ME 450 Combustion 4R-0L-4C Prereq: ME 301

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises.

ME 461 Aircraft Design 4R-0L-4C W Prereq: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams.

ME 462 Thermal Design 4R-0L-4C W,S Prereq: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Capstone Design I 2R-3L-3C F, S Prereq: ES205, EM204, ME301, and Junior Standing

Students work in teams with three to five members on design projects furnished from clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in interim reports which are submitted to the clients.

ME 471 Capstone Design II 1R-4L-3C F, W Prereq: ME 470

This course is a continuation of ME470. Students continue work in teams with three to five members developing the project started in ME470. The emphasis is on detailing design solutions identified in the first quarter. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in interim reports which are submitted to the clients. This course is intended to be taken in the quarter immediately following ME470.

ME 472 Capstone Design III 1R-4L-3C W,S Prereq: ME 471

This course is a continuation of ME 471. The student teams test their prototype solutions and transfer the project results to their client. Continuous and regular communication with the outside clients, as well as with the faculty advisors, is expected. The course culminates with a final report that documents the design process. This course is intended to be taken in the quarter immediately following ME471.

ME 480 Machine Component Design 4R-0L-4C S & F Prereq: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Completion of freshman and sophomore course requirements and approval of adviser and course instructor

Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Senior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged

Topics of current interests in mechanical engineering.

ME CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

ME 501 Advanced Thermodynamics 4R-0L-4C F Prereq: ME 301 or equivalent

Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.

ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Prereq: ME 302

Course may be repeated for different heat transfer topics.

ME 503 Viscous Fluid Flow 4R-0L-4C Prereq: ME 401

Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.

ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Prereq: ES 205, MA 212

Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.

ME 506 Advanced Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.

ME 507 Applied Nonlinear Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liapunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.

ME 510 Gas Dynamics 4R-0L-4C F Prereq: ES 202

Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas

flow with friction and heat transfer.

ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Prereq: ES 205 and ME 323

Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

ME 512 Light Weight Structures 4R-0L-4C S Prereq: MA 212 and EM 203 or EM 204

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

ME 513 Environmental Noise 4R-0L-4C F Prereq: Senior class standing

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

ME 518 Advanced Kinematics 4R-0L-4C S Prereq: ME 403

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ECE 519, EP 511, and CHE 519.

ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Prereq: EM 104 and Senior class standing

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

ME 522 Advanced Finite Element Analysis 4R-1L-4C S Prereq: ME 422

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

ME 526 Turbomachinery 4R-0L-4C Prereq: ES 205 or equivalent, or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency. Students enrolled in ME 526 must complete a design project including complexities not covered in ME 426. Students may not receive credit for both ME 426 and ME 526

ME 527 Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution. Students enrolled in ME 527 must complete a design project not covered in ME 427. Students may not receive credit for both ME 427 and ME 527.

ME 536 Computational Intelligence in Control Engineering 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Machine learning and adaptation applied to feedback control, guidance and navigation. Neural Networks for pattern recognition, modeling and control. Radial basis function model identification by recursive least squares.

Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.

ME 547 Visualizing Data 4R 0L 4C. Prereq: Graduate standing and instructor consent.

Same as ME 447 with the added requirement that the course is open only to graduate students having a graduate project or thesis generating quantitative data that the course instructor has agreed meets the 500 level course objectives.


ME 550 Combustion 4 R-0L-4C Prereq: ME 301

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises. Students enrolled in ME 550 must complete a design project not covered in ME 450. Students may not receive credit for both ME 450 and ME 550.

ME 590 Thesis Research F,W,S

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S



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News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Prereq: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

MDS 402 Seminar in Sustainability 2R-0L-2C Pre: Junior class standing and approval of certificate advisors
Provides students with the opportunity to examine, analyze, and reflect upon sustainability and sustainable engineering projects. Course work includes weekly readings and discussions, individual essays, and in-class and public presentations. Enrollment is open to all students, with first priority given to those pursuing the Certificate in Sustainability Studies. Permission to enroll is contingent upon students' previous sustainability project experience (curricular and / or co-curricular) as approved by certificate advisors.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

OE 171 Photography and Holography 2R-0L-2C F
Introduce students to basic knowledge of optics, principles and operation of a camera, shutters, films, and film development, color photography. Basic understanding of interference of waves, concept of holography, properties of various holograms, application of holography, and each student makes an individual hologram that can be seen in sunlight.

OE 172 Lasers and Fiber Optics 2R-0L-2C S
Light, optics, image formation, and optical instruments. Introduction to the properties, physics of operation, types, and applications of lasers. Characteristics of optical fibers and optical communication systems. Applications of lasers and fibers in industry, medicine, and consumer products. Laser safety.

OE 280 Geometrical Optics 3.5R-1.5L-4C W Prereq: PH 113
First-order optics including graphical ray tracing, Gaussian methods, y-nu ray tracing, cardinal points, apertures, stops, pupils, vignetting, and obscuration. Optical invariant, dispersion, chromatic aberrations, glass selection, exact ray tracing, third-order monochromatic aberrations, introduction to computer-aided design and analysis. Relevant laboratory experiments.

OE 290 Directed Research Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 295 Photonic Devices and Systems 3.5R-1.5L-4C S Prereq: PH 113 and MA 211
Optical radiation, radiometry, and photometry. Blackbody radiation and thermal sources. Introduction to optoelectronic devices. Light emitting diodes and other optical sources. Optical detectors (thermal, photoemissive, and semiconductor detectors). Sources/effects of noise and SNR. Flux transfer in optical systems. Relevant laboratory experiments.

OE 360 Optical Materials 4R-0L-4C W (every other year) Prereq: PH 255 and PH 316
Electromagnetic waves in dielectrics/metals and complex refractive index. Optical, thermal, and mechanical properties of materials. Thin film interference, optical coatings, and design of multilayer films. Optical characterization of materials. Electromagnetic waves in anisotropic materials, double refraction, optical activity, and polarization devices.

OE 392 Linear Optical Systems 4R-0L-4C F Prereq: PH 292 and MA 212
Propagation of light and scalar diffraction theory. Fraunhofer and Fresnel diffraction, coherence, Fourier series and transforms, convolution and correlation. Linear system theory, impulse and step response, transfer functions. Coherent and incoherent image formation, optical transfer function (OTF), modulation transfer function (MTF). Image quality assessment methods. Optical information processing applications.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Biomathematics
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

OE 393 Fiber Optics and Applications 3.5R-1.5L-4C W (every other year) Prereq: OE 295 & PH 316 or ECE 341 or consent of instructor

Basic dielectric waveguide equations; wave optics and ray optics; step-index and graded-index fibers; single mode and multi-mode fibers; mode cutoff conditions; numerical aperture; fabrication of optical fibers; fiber measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems. Relevant laboratory experiments.

OE 395 Optomechanics & Optical Engineering Lab 2R-6L-4C F Prereq: PH 292, OE 280, and OE 295

Design, assembly, and alignment of bench top optical systems. Introduction to experimental techniques in optics. Data collection and analysis. Relevant lecture topics including principles of opto-mechanical design, fold mirrors and prisms, lens and mirror mounting, kinematic mounts, precision adjustments and control.

OE 415 Optical Engineering Design I 2R-6L-4C S Prereq: OE 280 or EP 280 and JR/SR standing Coreq: RH 330

Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415.

OE 416 Optical Engineering Design II 2R-6L-4C F Prereq: OE 415

Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE 417 Optical Engineering Design III 2R-6L-4C W Prereq: OE 416

Continuation of OE 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with EP 417.

OE 434 Non-Imaging Optics 4R-0L-4C S (every other year) Prereq: OE 295

Lighting, illumination, and solar concentration systems. Radiometry and photometry for illumination, etendue, and concentration. Color coordinates, color vision, and color measurements. Sources, light transfer components, and systems evaluation. Introduction to design methods (edge-ray, compound parabolic concentrator, tailored reflector). Design examples and case studies.

OE 435 Biomedical Optics 4R-0L-4C W Prereq: PH 113 and MA 212

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Cross-listed with BE 435.

OE 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments. Cross-listed with ECE 480.

OE 450 Laser Systems and Applications 3.5R-1.5L-4C S Prereq: PH 292 and MA 212

Ray transfer matrix methods, Gaussian beam propagation, and beam quality. Optical resonators and stability, longitudinal and transverse modes. Stimulated emission, population inversion, rate equations, gain and threshold. Q-switching and mode-locking. Applications and types of lasers. Laser safety and relevant laboratory experiments.

OE 470 Special Topics in Optical Engineering 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in optics.

OE 480 Optical System Design 4R-0L-4C F Prereq: OE 280

Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based optimization, tolerancing, and manufacturing considerations.

OE 490 Directed Research Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S (every other year) Prereq: OE 393

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments.

OE 495 Optical Metrology 3.5R-1.5L-4C W Prereq: OE 280 and OE 392

Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

OE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Prereq: GR standing

Introduction to optics for incoming graduate students. Geometric optics; wave optics; sources and detectors. Students progressing towards or holding a bachelor's degree in Optical Engineering may not receive credit for OE 520.

OE 535 Biomedical Optics 4R-0L-4C W Prereq: PH 113, MA 212, and SR standing or GR standing

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 435 and OE 535. Cross-listed with BE 535.

OE 537 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 120 or ME 123 and SR standing or GR standing.

Introduction to image segmentation and recognition. Use of neural networks, fuzzy logic and morphological methods for feature extraction. Advanced segmentation, detection, recognition and interpretation. Relevant laboratory experiments and required project. Cross-listed with ECE 582.

OE 570 Special Topics in Optics 2 or 4C F, W, S Prereq: Consent of instructor and SR or GR standing

Lectures on contemporary topics in optical science, optical engineering, and photonics.

OE 580 Optical System Design 4R-0L-4C F Prereq: OE 280 and SR standing or GR standing

Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based optimization, tolerancing, and manufacturing considerations. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 480 and OE 580.

OE 585 Electro-Optics and Applications 3R-3L-4C W Prereq: PH 292, PH 316 and SR standing or GR standing

Optical wave propagation in anisotropic media. Normal surface and the index ellipsoid. Double refraction. Optical activity and Faraday rotation. Pockels and Kerr effects. Electrooptic modulators. Acousto-optic effect. Modulators and scanners. Introduction to nonlinear optics. Second-harmonic generation and frequency doubling. Relevant laboratory experiments.

OE 592 Fourier Optics and Applications 3.5R-1.5L-4C W Prereq: OE 392 and SR standing or GR standing

Two-dimensional linear systems. Scalar diffraction theory, Fresnel & Fraunhofer diffraction. Coherent optical systems analysis. Frequency analysis of optical imaging systems. Spatial filtering and analog optical information processing. Wavefront reconstruction and holography. Relevant laboratory experiments.

OE 593 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S (every other year) Prereq: OE 393 and SR standing or GR standing

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties, dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 493 and OE 593.

OE 594 Integrated Optics 4R-0L-4C F Prereq: OE 393 and SR standing or GR standing

Theory of dielectric optical waveguides. Waveguide modes. Coupled-mode formalism and periodic structures. Input and output coupling of optical beams to planar structures. Waveguide losses. Phase, frequency and polarization modulators. Waveguide gratings, electro-optic modulators, and switching. Applications of integrated optics.

OE 595 Optical Metrology 3.5R-1.5L-4C W Prereq: OE280, OE392 or SR/GR standing or consent of instructor; Coreq OE480

Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 495 and OE 595.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Physics

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

Accelerated Math Physics Program - MA113, PH111, PH112 12R-3L-13C Prereq: One year of college level calculus (BC Calculus or equivalent), one year of high school physics, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Accelerated Math Physics Program Selection Committee.

A 5-week intensive immersion into calculus and physics which covers the equivalent of Calculus III, and Physics I, II. Taught only to incoming freshman who have demonstrated outstanding ability in both calculus and physics. Review of single variable calculus, both differential calculus and integral calculus, as needed. Covers from MA113: vectors and parametric equations in three dimensions, functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems with applications of vectors, parametric equations, partial derivatives and multiple integrals. Covers from PH111, PH112: kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, conservation of energy and momentum, torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, with relevant laboratory experiments.

PH 090 College Preparatory Physics 4R-0L-4C Prereq: College Algebra II
Topics covered include: Units, significant figures, vectors, 1 and 2 dimensional motion; kinematic equations, objects in free-fall, motion in a circle, projectile motion, Newton's Laws, contact forces, non-contact forces: gravity, Coulomb's Law, magnetic force; centripetal force; collisions, linear momentum, rotational kinematics, torques, angular momentum, mechanical equilibrium - static equilibrium. The credits from this course cannot be counted toward any degree completion at Rose-Hulman.

PH 111 Physics I 3.5R-1.5L-4C F,W Coreq: MA 111
Kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, strong and weak nuclear forces, conservation of energy and momentum, relevant laboratory experiments.

PH 112 Physics II 3.5R-1.5L-4C W,S Prereq: PH 111 and MA 111; Co: MA 112
Torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, relevant laboratory experiments.

PH 113 Physics III 3.5R-1.5L-4C S,F Prereq: PH 112 and MA 112; Coreq: MA 113
Sources of magnetic fields, Faraday's law, inductance electromagnetic waves, reflection and polarization, geometric and physical optics, introduction to relativity, relevant laboratory experiments.

PH 200 Career Preparation 1R-0L-1C W,S
This course is for physics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, MA200 and SV200.

PH 215 Introduction to CHAOS 2R-0L-2C W
What constitutes chaotic behavior, detection of chaos in real systems using phase space plots, Poincare

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

sections, bifurcation plots, power spectra, Lyapunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Prereq: MA 111, and PH 111 or EM 120

Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Prereq: PH 111 or Coreq: EM 202; and Coreq: MA 112

Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Prereq: MA 111, and PH 111 or EM 120

Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Prereq: MA 111 and PH 111 or EM 120

Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Prereq: PH 113 and Coreq: MA 211

Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Prereq: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Prereq: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Prereq: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Prereq: PH 113

The wave equation; electromagnetic waves; phase and group velocities; complex refractive index; dispersion, interference; interferometers and applications, optical interferometry; coherence; polarized light; Jones vectors/matrices; production of polarized light; birefringence, Fraunhofer diffraction; diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Prereq: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Prereq: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S Arranged Prereq: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W Arranged Prereq: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Prereq: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Prereq: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Prereq: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Prereq: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication, transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Prereq: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Prereq: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schroedinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schroedinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Prereq: PH 113 and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Cross-listed with PH 505.

PH 407 Solid State Physics 4R-0L-4C S (even years) Prereq: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 410 General Relativity 4R-0L-4C W (odd years) Pre: PH 310 and MA 421

An in-depth study of Einstein's theory of General Relativity. Gravity as geometry and curved space-time, metrics, and geodesics. Orbits and light paths around spherical masses. Detailed study of Einstein's equation in vacuum and with sources of space-time curvature.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Prereq: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Prereq: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Prereq: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must

make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

PH CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Prereq: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Prereq: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Prereq: Consent of instructor

Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.



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Spring Term		Credit
BIO 230	Eukaryotic Cell & Molecular Biology	4
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
PH 113	Physics III	4
MA 223	Engineering Statistics	4
Total		16

Junior Year

Fall Term		Credit
BIO 320	Ecology	4
CHEM 330	Biochemisty	4
HSS	Elective	4
BIO 399	Practice of Science	4
Total		16

Senior Year

Fall Term		Credit
BIO 498	Senior Thesis Research III	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16

Winter Term		Credit
BIO 330	Evolutionary Biology	4
BIO 496	Senior Thesis Research I	2
BIO	Elective	4
HSS	Elective	4
Total		14

Winter Term		Credit
BIO 499	Senior Thesis Research IV	2
	Science/Technical Elective	4
BIO	Elective	4
HSS	Elective	4
Total		14

Spring Term		Credit
BIO 310	Plant Structure & Function	4
BIO 497	Senior Thesis Research II	4
SV 304	Bioethics	4
HSS	Elective	4
Total		16

Spring Term		Credit
BIO	Elective	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16
Total credits required:		188

A BIO science/technical elective is any Rose-Hulman course that has a prefix of BIO, BE, CHEM, CHE, CE, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required BIO courses	52 credits
BIO electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	12 credits
Required MA, CHEM, PH	63 credits
Required CLSK	1 credit
Sci/Tech electives	12 credits
Required BE course	4 credits
Total	188 credits

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility. Two faculty are directly involved with this program: Dr. Mark Brandt, assistant professor of chemistry, is the program coordinator and is a biochemist, and Dr. Richard Anthony, associate professor of biology, is a molecular biologist. Many other faculty in both the chemistry and biology departments assist with this curriculum.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the

student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required Courses

Elective Courses

Choose 12 credits* from the following courses:

Course	Description	Hours
CHEM 111, 113, 115	General Chemistry	12
CHEM 251, 252, 253	Organic Chemistry	9
CHEM 251L, 252L, 253L	Organic Chemistry Lab	3
CHEM 330, 430, 433	Biochemistry	9
CHEM 361, 362 or CHEM 360 and		
CHE 303, 304	Physical Chemistry	8
BIO 110, 120, 130	Biology	12
BIO 210	Genetics	4
BIO 220, 230	Molecular Biology	8
BIO 411	Genetic Engineering	4
Total		69

Course	Description
BIO 330	Evolutionary Biology
BIO 421	Microbiology
BIO 431	Genomics and Proteomics
BIO 441	Virology
BIO 451	Cancer Biology
BIO 492	Directed Study in Biology
CHEM 225	Analytical Chemistry
CHEM 291	Introduction to Research
CHEM 331	Biochemistry II
CHEM 431	Biochemical Instrumentation
CHEM 451	Organic Structure Determination
CHEM 290 or	
CHEM 490	Chemical Research
PH 302	Biophysics

Total Credits for Second Major 81

**Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the BIO electives listed, and 4 credits chosen from any BIO or BE course.*

STUDENTS WITH A MAJOR IN BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above BIO course (total: 29 hours required beyond Biology major).

Biology Area Minor

The Area Minor in Biology is designed to allow students to enrich studies in their major area. Students wishing to apply another science, mathematics, or engineering discipline to investigate or solve problems in biological systems are encouraged to pursue the Area Minor in Biology. With proper course selection, the Area Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Area Minor in Biology has the following requirements.

1. All students must complete BIO110 (Cell Structure and Function) or BIO130 (Evolution and Diversity) and at least four more courses in biology (BIO) or allied areas, above those courses already specifically required to fulfill the student's major.
 - a. At least three of the four electives must be BIO courses.
 - b. At least three of the electives must be 200-level or above.Additional courses not listed in the approved allied areas can be considered on a case-by-case basis. See BBE Department Head.
2. Students electing to pursue the Area Minor in Biology must follow a plan of study that is approved by the Area Minor Advisor. Current advisor information and a form for the planning and approval of an area minor can be obtained from the BBE Department secretary.

3. Allied area courses could include:
- BE 310 Analysis of Physiological Systems I
 - BE 320 Analysis of Physiological Systems II
 - BE/MA 482 Bioengineering Statistics
 - BE 570 Introduction to Tissue Engineering
 - CE 460 Introduction to Environmental Engineering
 - CHE 545 Introduction to Biochemical Engineering
 - CHEM 264 Environmental Chemistry
 - CHEM 330 Survey of Biochemistry
 - CHEM 430 Advanced Biochemistry
 - PH 302 Biophysics
 - SL 386 Human Evolution
 - VA 373 Gender Issues

Biochemistry & Molecular Biology Area Minor

Completion of BIO110, CHEM111, CHEM113 and CHEM115. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

Course	Description
BIO 210	Mendelian and Molecular Genetics
BIO 220	Prokaryotic Cell and Molecular Biology
or	
BIO 230	Eukaryotic Cell and Molecular Biology
BIO 411	Genetic Engineering
or	
BIO 431	Genomics and Proteomics
CHEM 230	Introduction to Organic Chemistry and Biochemistry
or	
CHEM 251 and	Organic Chemistry I
CHEM 252	Organic Chemistry II
CHEM 330	Biochemistry
CHEM 430	Advanced Biochemistry
with	
CHEM 433	Biochemistry Laboratory



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Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

BIOCHEMISTRY PLAN OF STUDY

Freshman Year

Fall Term		Credit
CHEM 111*	General Chemistry I	4
MA 111	Calculus I	5
BIO 110	Cell Structure & Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		18

Winter Term		Credit
CHEM 113*	General Chemistry II	4
MA 112	Calculus II	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		17

Spring Term		Credit
CHEM 115	General Chemistry III	4
MA 113	Calculus III	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
PH 113	Physics III	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
BIO 210	Mendelian & Molecular Genetics	4
Total		16

Winter Term		Credit
CHEM 200	Career Preparation	1
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
CHEM 291	Intro to Undergraduate Research	4
MA 381	Introduction to Probability with Applications to Statistics	4
BIO 220	Prokaryotic Cell & Molecular Biology	4
Total		16

Spring Term		Credit
CHEM 253	Organic Chemistry III	3

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

CHEM 253L	Organic Chemistry III Lab	1
CHEM 225	Analytical Chemistry	4
BIO 230	Eukaryotic Cell & Mol. Biology	4
RH 330	Technical Communication	4
Total		16

Junior Year

Fall Term		Credit
CHEM 326	Bioanalytical Chemistry	4
CHEM 330	Biochemistry I	4
CHEM 361	**Physical Chemistry I	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 395	Chemistry Seminar	0
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

Winter Term		Credit
CHEM 327	Advanced Analytical	4
CHEM 362	**Physical Chemistry II	4
CHEM 331	Biochemistry II	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

Spring Term		Credit
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 430	Advanced Biochemistry	4
CHEM 433	Biochemistry Lab	1
HSS	Elective	4
CHEM 490	Research	1
Total		14 or 15

Senior Year

Fall Term		Credit
CHEM 441	Inorganic Chemistry I	4
CHEM 495	Chemistry Seminar	0
CHEM 490	Chemistry Research	1
CHEM 491	Research Thesis (F, W or S)	1
##Advanced Chemistry or Biochemistry Elective		4
Advanced Biology Elective		4
Free Elective		4
Total		17 or 18

Winter Term		Credit
CHEM 496	Chemistry Seminar	0
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
##Advanced Biology, Chemistry, Biochemistry Elective		4
Free Elective		4
Total		12, 13, or 14

Spring Term		Credit
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Free Elective		4
Free Elective		4
Total		12, 13, or 14
Total credits required:		192

Notes: Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441	4
Biochemistry	330, 331, 430, 433	13
Research	291, 490	8
Chemical Communication	400, 401, 402, 403	4
Career Preparation	200	1
Electives		8
Total		86

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total
Chemistry	78	8	86
Physics	12	0	12
Mathematics	23	0	23
Biology	20	0	20
Humanities and Social Sciences	4	32	36
Electives	0	16	16
College and Life Skills	1	0	1
Total	136	56	194

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM111	General Chemistry I	4
CHEM113	General Chemistry II	4
CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		32

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	
or CHEM253	Organic Chemistry III	4
CHEM330	Biochemistry I	
or CHEM361	Physical Chemistry I	4
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

- be able to design and conduct experiments, making measurements from both living and non-living systems.
- be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- be able to function in multidisciplinary teams in different roles.
- be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- have the skills required for self-learning.
- be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit
BIO 110	Cell Structure and Function	4
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
EM 104	Graphical Communication	2
Total		16

Winter Term		Credit
BIO 120	Comparative Anatomy & Physiology	4
PH 112	Physics II	4
MA 112	Calculus II	5
EM 121	Statics and Mechanics of Materials I	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
RH 131	Rhetoric & Composition	4
MA 113	Calculus III	5
BE 100	Problem Solving in the Biological Sciences and Engineering	4
Total		17

Junior Year

Fall Term		Credit
HSS	Elective	4
BIO 205	Cellular Physiology	4
	Tech & Profess'l Comm	4

Sophomore Year

Fall Term		Credit
ES 201	Conservation & Accounting Principles	4
CHEM 111	General Chemistry I	4
MA 211	Differential Equations	4
ES 203	Electrical Systems	4
Total		16

Winter Term		Credit
ES 202	Fluid and Thermal Systems	3
ES 204	Mechanical Systems	3
MA 212	Matrix Algebra and Systems of Differential Equations	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		18

Spring Term		Credit
BE 201	Biomedical Measurements	4
BIO 130	Evolution and Diversity	4
ES 205	Analysis & Design of Engineering Systems	4
MA 223	Engineering Statistics	4
Total		16

Senior Year

Fall Term		Credit
BE 410	Biomedical Engineering Design I	4
HSS	Elective	4

HSS or RH330	or HSS Elective	
EM 204	Statics and Mechanics of Materials II	4
Total		16
Winter Term		Credit
BE 310	Physiological Systems I	4
BE 331	Biomechanics	3
BE 351	Biomedical Engineering Lab	2
BE 361	Biomaterials	3
HSS or RH330	HSS Elective or Tech & Profess'l Comm	4
Total		16
Spring Term		Credit
SV 304	Bioethics	4
BE 320	Physiological Systems II	4
BE 390	Principles of Biomedical Engineering Design	2
BE	Area	4
Total		14

	Free Elective	4
BE	Area Elective	4
Total		16
Winter Term		Credit
BE 420	Biomedical Engineering Design II	4
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
Total		16
Spring Term		Credit
BE 430	Biomedical Engineering Design III	2
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
Total		14
Total credits required:		192

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the ABBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 417	Advanced Materials
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanincs
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both
**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols

BE 516	Introduction to MEMS
BE 435/535	Biomedical Optics
BE 555	Electrophysiology
ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course	Title
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
BE 525	Biomedical Fluid Mechanics
BE 531	Biomechanics II
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopaedic Biomechanics
BE 550	Research Methods in Biomechanics
EM 403	Advanced Mechanics of Materials
ME 422	Finite Elements for Engineering Applications
ME 520	Computer-Aided Design and Manufacturing
ME 522	Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Area Minor

The biomedical engineering area minor is intended to provide a strong biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and the health care related fields.

In order to complete the requirements in the biomedical engineering area minor, a student must complete AB110 "Cell Structure and Function" and 16 credits from list shown below. At least three of the courses must have a BE prefix.

Biomedical Engineering Minor Electives

Course	Credits	Title
PH 302	4	Biophysics
BIO 411	4	Genetic Engineering
BE 310	4	Analysis of Physiological Systems I
BE 320	4	Analysis of Physiological Systems II
BE 331	3	Biomechanics
BE 340	4	Biomedical Instrumentation
BE 350	4	Biocontrol Systems
BE 351	2	Biomedical Engineering Lab *
BE 352	1	Biomechanics Lab *
BE 353	1	Biomaterials Lab *
BE 361	3	Biomaterials

BE 435/535	4	Biomedical Optics
BE 482	4	Bioengineering Statistics
BE 510	4	Biomedical Signal and Image Processing
BE 525	4	Biomedical Fluid Mechanics
BE 531	4	Biomechanics II
BE 534	4	Soft Tissue Mechanics
BE 539	4	Multiscale Biomechanics
BE 541	4	Medical Imaging
BE 543	4	Neuroprosthetics
BE 545	4	Orthopaedic Biomechanics
BE 550	4	Research Methods in Biomechanics
BE 555	4	Electrophysiology
BE 560	4	Tissue-Biomaterial Interactions
BE 570	4	Introduction to Tissue Engineering

*Students getting credit for BE351 cannot get credit for BE352 or BE353.

In addition to courses on the above list, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

Basic Engineering Courses

Course	Title
EM 121	Statics and Mechanics of Materials I
EM 204	Statics and Mechanics of Materials II
EM 301	Fluid Mechanics
ECE 130	Introduction to Logic Design
ECE 200	Circuits & Systems
ES 201	Conservation & Accounting Principles
ES 202	Fluid & Thermal Systems
ES 203	Electrical Systems
ES 204	Mechanical Systems
CHE 201	Conservation Principles and Balances
CHE 202	Basic Chemical Process Calculations
CHE 301	Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the Head of the Department of Applied Biology and Biomedical Engineering.



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

- Our graduates will attain a promotion and/or responsibilities beyond their entry-level position, or progress toward the completion of an advanced degree.
- Our graduates will continue to develop professionally.
- Our graduates will collaborate professionally within or outside of their organizations at a regional, national and/or international level.
- Our graduates will participate in service to their professions and/or community organizations.

Student Outcomes

Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning

Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

11. A knowledge of contemporary issues

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4
Total		16

Winter Term		Credit
CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5
PH 111	Physics I	4
HSS	Elective	4
Total		17

Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Freshman Year (A2 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4
Total		16

Winter Term		Credit
CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5
PH 111	Physics I	4
HSS	Elective	4
Total		17

Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Sophomore Year (A1 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4

Sophomore Year (A2 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4

EM 101	Statics I	2
Total		14

<i>Winter Term</i>		<i>Credit</i>
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
HSS	Elective	4
Total		16

Junior Year (A1 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
CHE 315	Materials Science	4
CHEM 225	Analytical Chemistry I	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CHE 321	Applications of Heat and Mass Transfer	4
CHEM 360	Intro Physical Chemistry	4
MA 223	Engineering Statistics I	4
RH 330	Technical and Professional Communication	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CHE 404	Kinetics & Reactor Design	4
CHE 411	Chemical Engineering Lab I	3
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
Total		15

Senior Year (A1 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4

EM 101	Statics I	2
Total		14

<i>Winter Term</i>		<i>Credit</i>
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
MA 223	Engineering Statistics I	4
CHEM 225	Analytical Chemistry I	4
HSS	Elective	4
CHE 315	Materials Science	4
Total		16

Junior Year (A2 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
RH 330	Technical and Professional Communication	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CHE 321	Applications of Heat and Mass Transfer	4
CHE 411	Chemical Engineering Lab I	3
CHEM 360	Intro Physical Chemistry	4
HSS	Elective	4
Total		15

Senior Year (A2 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 404	Kinetics & Reactor Design	4
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab	4

CHE 416	Design I	4	II		
	Free Elective(Free)	4	CHE 416	Design I	4
	Free Elective(CHE)	4		Free Elective(Free)	4
	Total	17		Total	17
<i>Winter Term</i>			<i>Winter Term</i>		
	<i>Credit</i>			<i>Credit</i>	
CHE 413	Chemical Eng. Lab III	4	CHE 413	Chemical Eng. Lab III	4
CHE 417	Design II	4	CHE 417	Design II	4
CHE 440	Process Control	4	CHE 440	Process Control	4
HSS	Elective	4	HSS	Elective	4
	Total	16		Total	16
<i>Spring Term</i>			<i>Spring Term</i>		
	<i>Credit</i>			<i>Credit</i>	
CHE 418	Design III	2	CHE 418	Design III	2
HSS	Elective	4	HSS	Elective	4
HSS	Elective	4		Elective(CHE)	4
	Elective(Approved)	4		Elective(CHE)	4
	Elective(CHE)	4		Elective(Approved)	4
	Total	18		Total	18
	Total credits required:	194		Total credits required:	194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 405 Introduction to MEMS: Fabrication and Applications
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see

below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Area Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 320 Fundamentals of Heat and Mass Transfer
- CHE 321 Applications of Heat and Mass Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Area Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- AB110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology
- or
- AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering
- AB421 - Applied Microbiology
- AB431 - Genomics and Proteomics
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary

AREA OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. Students may not count courses towards a concentration that also count towards another concentration or towards a minor, certificate, double major, or second degree. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 450 Air Pollution
- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT534 Management Science
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include biology, chemical engineering and mathematics.

CHEMISTRY PLAN OF STUDY

Freshman Year

Fall Term		Credit
CHEM 111*	General Chemistry	4
MA 111	Calculus I	5
BIO 110**	Cell Structure and Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		18

Winter Term		Credit
CHEM 113*	General Chemistry II	4
MA 112	Calculus II	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
HSS	Elective	
Total		17

Spring Term		Credit
CHEM 115	General Chemistry III	4

Sophomore Year

Fall Term		Credit
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
PH 113	Physics III	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Free Elective	4
Total		16

Winter Term		Credit
CHEM 200	Career Preparation (take in winter or spring)	1
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
CHEM 291	Intro to Undergraduate Research	4
MA 381	Introduction to Probability with Applications to Statistics	4

Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

MA 113	Calculus III	5
HSS	Elective	4
PH 112	Physics II	4
Total		17

Free Elective		4
Total		16 or 17
<i>Spring Term</i>		<i>Credit</i>
CHEM 200	Career Preparation (take in winter or spring)	1
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
CHEM 225	Analytical Chemistry I	4
HSS	RH 330	4
Free Elective		4
Total		16 or 17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CHEM 326	Bioanalytical Chemistry	4
CHEM 361	***Physical Chemistry I	4
CHEM 330	Biochemistry I	4
CHEM 391	Research Proposal (F,W or S)	1
CHEM 395	Chemistry Seminar	0
CHEM 490	Research	1
HSS	Elective	4
Total		17 or 18

<i>Winter Term</i>		<i>Credit</i>
CHEM 327	Advanced Analytical	4
CHEM 362	***Physical Chemistry II	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 490	Research	1
HSS	Elective	4
Free Elective		4
Total		17 or 18

<i>Spring Term</i>		<i>Credit</i>
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 391	Research Proposal (F, W or S)	1
CHEM 451	Organic Structure Determination	4
HSS	Elective	4
Free Elective		4
CHEM 490	Research	1
Total		17 or 18

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CHEM 441	Inorganic Chemistry I	4
CHEM 490	Research	1
CHEM 491	Research Thesis (F, W or S)	1
CHEM 495	Chemistry Seminar	0
CHEM 497	Research Presentation (F, W or S)	1
Chemistry Elective		4
Free Elective		4
Total		13, 14, or 15

<i>Winter Term</i>		<i>Credit</i>
CHEM 442	Inorganic Chemistry II	4
CHEM 491	Research Thesis (F, W or S)	1
CHEM 496	Chemistry Seminar	0
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Chemistry Elective (400-level)###		4
Total		12, 13, or 14

<i>Spring Term</i>		<i>Credit</i>
CHEM 491	Research Thesis (F, W or S)	1
CHEM 497	Research Presentation (F, W or S)	1
HSS	Elective	4
Free Elective		4
Free Elective		4
Total		12, 13, or 14
Total credits required:		191

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM 111 General Chemistry I is an automatic substitution for the former CHEM 105 Engineering Chemistry I.

CHEM 113 General Chemistry II is an automatic substitution for the former CHEM 107 Engineering Chemistry II.

*BIO 120 or BIO 130 may be substituted for BIO 110

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Summary of minimum graduation requirements:

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441, 442	4
Biochemistry	330	4
Organic Structure Determination	451	4
Chemical Communication	400, 401, 402, 403	4
Research	291, 490	8
Career Preparation	200	1
Electives		8
Total		85

Course or areas	Required	Elective	Total
Chemistry	77	8	85
Physics	12	0	12
Mathematics	23	0	23
Biology	4	0	4
Humanities and Social Sciences	4	32	36
Electives	0	32	32
College and Life Skills	1	0	1
Total	121	76	193

Area Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in biology or chemical engineering are different from those majoring in other disciplines.

Area Minor in Chemistry for Most Students

Course Number	Course Title	Credits
CHEM 113	General Chemistry II	4
CHEM 115	General Chemistry III	4
CHEM 225	Analytical Chemistry	4
CHEM 251	Organic Chemistry I	4
CHEM 252	Organic Chemistry II	4
*Approved List of		4

Chemistry Electives	
Total	24

*Approved list of chemistry electives include CHEM 253, CHEM 290 (up to two credit hours), CHEM 291, or any 300 or 400 level chemistry courses.

Area Minor in Chemistry for Chemical Engineering and Biology Majors

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student's major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
CHEM 115	General Chemistry III	4
CHEM 225	Analytical Chemistry	4
CHEM 251	Organic Chemistry I	4
CHEM 264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHEM 465	Energy and the Environment	4
Total		32

Environmental Chemistry Minor for Chemical Engineers and Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
or CHEM 330	Biochemistry	4
CHEM 361	Physical Chemistry I	4
or CHE 303	Chemical Engineering Thermodynamics	4
CHEM 264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHE 465	Energy and the Environment	4
Total		24



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four technical areas appropriate to civil engineering.

- 4. **Engineering Impact** - Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- 5. **Contemporary Issues** - Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.
- 6. **Design** - Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- 7. **Multidisciplinary** - Function effectively as a member of a multidisciplinary team.
- 8. **Professional/Ethical** - Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- 9. **Communication** - Organize and deliver effective verbal, written, and graphical communications.
- 10. **Engineering Tools** - Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.
- 11. **Life Long Learning** - Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- 12. **Leadership** - Apply leadership principles to direct the efforts of a small group.
- 13. **Service** - Use one's time and skills to benefit an individual or community without cost to the recipient.
- 14. **Project Management** - Explain key concepts in project management, and develop solutions to well-defined project management problems.
- 15. **Business and Public Administration** - Explain key concepts and processes used in business, public policy, and public administration.
- 16. **Cultural and Global Awareness** - Analyze and interpret cultural perspectives and social systems that define human characteristics.

* The civil engineering program uses the term "educational objective" to describe the expected accomplishments of our students in three to five years following graduation. The term "student learning outcome" is used to describe knowledge and skills at the time of graduation.

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Civil Engineering PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition or Elective(HSS)	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
Total		16

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
RH 131	Rhetoric and Composition or Elective(HSS)	4
CE 111	Geographic Info Systems	2
Total		15

Spring Term		Credit
MA 113	Calculus III	5
EM 103	Introduction to Design	2
EM 120	Engineering Statics	4
CE 101	Engineering Surveying I	2
Elective (Science)***		4
Total		17

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
CHEM 111	General Chemistry I	4
EM 202	Dynamics	4
HSS	Elective	4
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
EM 203	Mechanics of Materials	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		16

Spring Term		Credit
MA 223	Statistics for Engineers	4
EM 301	Fluid Mechanics	4
CE 250	Sustainable Civil Engineering Design	2
CE 320	C.E. Materials	4
CE 380	Transportation Engineering	4
Total		18

Junior Year

Fall Term		Credit
CE 321	Structural Mechanics I	4
CE 336	Soil Mechanics	4
ME 201	Thermodynamics	4
	or	
CHE 201	Conservation Principles and Balances	
CE 371	Hydraulic Engineering	4
Total		16

Winter Term		Credit
ECE 206	Elements of Electrical Eng. or	4
CHE 202	Basic Chemical Process Calculations	
CE 441	Construction Engineering	2
CE 432	Concrete Design I	3
CE 471	Water Resources Engineering	4
	Elective (Science)***	4
Total		17

Spring Term		Credit
CE 310	Civil Engineering Numerical Methods	2
CE 431	Steel Design I	3
CE 460	Environmental Engineering	4
RH 330	Technical and Professional Communication	4
CE 461	Environmental Engineering Lab	2
Total		15

Senior Year

Fall Term		Credit
CE 486	C.E. Design & Synthesis I	2
CE	**C.E. Elective	4
CE 450	C.E. Codes & Regulations	4
HSS	Elective	4
HSS	Elective	4
Total		18

Winter Term		Credit
CE 487	Technical System Design & Synthesis	2
CE 488	C.E. Design & Synthesis II	2
CE	**C.E. Elective	4
	*Elective (Technical)	4
CE 303	Engineering Economy	4
Total		16

Spring Term		Credit
CE 489	C.E. Design & Synthesis III	2
	*Elective(Technical)	4
HSS	Elective	4
HSS	Elective	4
CE 400	Career Preparation Seminar	0
Total		14
Total credits required:		194

***A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, or physics.**

****Student shall choose any 400 or 500 level CE elective course, designated with the "CE" prefix, as a CE Elective, in consultation with their advisor.**

*****At least 4 hours of science elective must be in a natural science outside Chemistry or Physics.**

Environmental Engineering Area Minor

The Environmental Engineering Area minor includes 6 required courses and 8 elective credit hours. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their interests.

The 6 required courses are as follows:

CE 460	Introduction to Environmental Engineering
CE 471	Water Resources Engineering
CHEM 264	Introduction to Environmental Science
CE 563/CHE 461	Unit Operations in Environmental Engineering
CE 564	Aquatic Environmental Chemistry
CHEM 251	Organic Chemistry I
CHEM 251L	Organic Chemistry I Laboratory

And 8 credit hours from the following courses:

CE 561/CHE 450	Air Pollution Control
CE 562	Treatability Studies
CE 565	Solid and Hazardous Waste Regulation and Treatment
CE 566	Environmental Management
CE 567	Applied Hydrologic Modeling
CE 568	Applied Contaminant Transport Modeling
CE 569	Environmental Systems Optimization
CE 573	Groundwater Analysis
CE 590	Special Problems
CE 598	Stream Restoration (Environmental River Mechanics)
CHE 465	Energy and the Environment
CHE 470	Safety, Health, and Loss Prevention
AB 320	Ecology and Environmental Biology

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Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;
2. Function independently and in leadership positions within multidisciplinary teams;
3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;
4. Adapt and independently extend their learning to excel in fields about which they are passionate;
5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.

CPE student outcomes

At the time of graduation, students will have demonstrated:

1. an ability to apply knowledge of mathematics, science, and engineering
2. an ability to design and conduct experiments, as well as to analyze and interpret data
3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
4. an ability to function on multidisciplinary teams
5. an ability to identify, formulate, and solve engineering problems
6. an understanding of professional and ethical responsibility
7. an ability to communicate effectively
8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context
9. a recognition of the need for, and an ability to engage in life-long learning
10. a knowledge of contemporary issues
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The computer engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

COMPUTER ENGINEERING PLAN OF STUDY

Freshman Year		Sophomore Year	
Fall Term	Credit	Fall Term	Credit

Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
Total		16

<i>Winter Term</i>		<i>Credit</i>
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Intro to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
Total		17

<i>Spring Term</i>		<i>Credit</i>
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
Total		17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
MA 275	Discrete & Combinational Algebra I	4
CSSE 232	Computer Architecture I	4
ECE 380	Discrete-Time Signals	4
	or	
ECE 320	or Linear Control Systems	
RH 330	Technical and Professional Communication	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
ECE 312	Communication Networks	4
HSS	Elective	4
CSSE 332	Operating Systems	4
	or	
CSSE 230	Data Structures and Algorithm Analysis	
	Math/Science Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
ECE 332	Computer Architecture II	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
Total		15

MA 211	Differential Equations	4
CHEM 111	General Chemistry I	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
CSSE 220	Object Oriented Software Development	4
ECE 250	Electronic Device Modeling	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
ECE 460	Engineering Design I	3
ECE 343	High Speed Digital Design	4
	Area Elective	4
HSS	Elective	4
Total		15

<i>Winter Term</i>		<i>Credit</i>
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
Total		18
Total credits required:		194

AREA ELECTIVES

At least two of the three Area Electives must bear an ECE prefix at the 400 level or above
At most one of the Area Electives can bear an ECE or CSSE prefix at the 300 level or above
Exceptions to this requirement may be granted by the ECE Department Head

TECHNICAL ELECTIVE - Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering as a free elective or technical elective. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, geology or physics course as a math science elective except those courses that are cross-referenced with any engineering courses.

COMPUTER ENGINEERING CORE COURSES

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE312	Communication Networks	4
ECE332	Computer Architecture II	4
ECE343	High Speed Digital Design	4
ECE362	Principles of Design	3
ECE380	Discrete-Time Signals and Systems	4
or	or	
ECE320	Linear Control Systems	
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

SECOND MAJOR IN COMPUTER ENGINEERING

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.

Course Number	Course Title	Credits
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE312	Communication Networks	4
ECE332	Computer Architecture II	4
ECE343	High Speed Digital Design	4
ECE380	Discrete-Time Signals and Systems	4
or	or	
ECE320	Linear Control Systems	
CSSE120	Introduction to Software Development	4

CSSE220	Object-Oriented Software Development	4
CSSE232	Computer Architecture I	4
CSSE332	Operating Systems	4
or	or	
CSSE230	Data Structures & Algor Analysis	
MA381	Intro to Probability w/ Apps to Stats	4
Total		64

AREA MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE160, ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Examples of Area Minors for Engineernig Physics and Optical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE180	Introduction to Signal Processing	4	ECE204	AC Circuits	4
ECE204	AC Circuits	4	ECE230	Introduction to Embedded Systems	4
ECE205	Circuits and Systems	4	ECE233	Introduction to Digital Systems	4
ECE300	Continuous-Time Signals Systems	4	ECE250	Electronic Device Modeling	4
ECE380	Discrete-Time Signals and Systems	4	ECE351	Analog Electronics	4
or	or				
ECE310	Communication Systems				

Examples of Area Minors for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Introduction to Signal Processing	4
ECE230	Introduction to Embedded Systems	4	ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4	ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4	ECE205	Circuits and Systems	4
ECE332	Computer Architecture II	4	ECE332	Computer Architecture II	4

Examples of Area Minors for Mechanical Engineering

Course	Course Title	Credits	Course	Course Title	Credits
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Number			Number		
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Introduction to Signal	4
ECE370	Power and Energy	4		Processing	
	Systems		ECE204	AC Circuits	4
ECE371	Sustainable Energy	4	ECE233	Introduction to Digital	4
	Systems			Systems	
ECE470	Power Systems I	4	ECE250	Electronic Device Modeling	4
ECE471	Industrial Power Systems	4	ECE351	Analog Electronics	4

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science

The Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The computer science curriculum is designed to prepare students for multiple careers in a rapidly changing environment. The department's courses emphasize fundamental concepts and techniques that will last longer than present technology.

Computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer architecture, programming languages, operating systems, and software engineering. Majors also complete important courses in closely related fields, e.g., discrete mathematics, digital logic design, and probability and statistics. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Courses in database systems, compilers, computer graphics, fractals and chaotic dynamical systems, artificial intelligence, theory of computation, analysis of algorithms, computer networks, computer vision, web-based information systems, and cryptography are available as advanced electives. A three-term senior project provides valuable practical experience in the specification, design, implementation, and documentation of large software systems. Qualified students can undertake independent study in advanced topics in computer science, participate in a research project with a faculty member, or complete a senior thesis.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

Computer science majors have diverse interests and career goals. Five free elective courses allow students to tailor their undergraduate education to their specific goals. Students planning to undertake graduate study in computer science usually take additional advanced courses in computer science, electrical engineering, and mathematics.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Computer science majors have unlimited access to the department's laboratories. Computer science majors are frequently employed by the computing center as user consultants, and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

Computer Science Program Educational Objectives

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Student Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering
13. Recognize the need for, and engage in, lifelong learning
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The computer science program is accredited by the Computing Accreditation Commission of ABET, www.abet.org

COMPUTER SCIENCE PLAN OF STUDY

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
Total		18
Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4
PH 112	Physics II	4
MA 112	Calculus II	5
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
Total		16
Winter Term		Credit
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
MA 375	Discrete & Combinatorial Algebra II	4

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

HSS	Elective	4
Total		16
<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Lang. Con.	4
ECE 332	Computer Architecture II	4
MA 381	Introduction to Probability with Applications to Statistics	4
RH 330	Technical and Professional Communication	4
Total		16

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 371	Software Requirements Engineering	4
CSSE/MA 473	Design and Analysis of Algorithms	4
CSSE	Elective	4
HSS	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
CSSE/MA 474	Theory of Computation	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE	Elective	4
	Technical Elective	4
Free	Elective	4
Free	Elective	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 487	Senior Research Project I or	4
CSSE 497	Senior Capstone Project I or	
CSSE 494	Senior Thesis I	
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 488	Senior Research Project II or	4
CSSE 498	Senior Capstone Project II or	
CSSE 495	Senior Thesis II	
CSSE	Elective	4
HSS	Elective	4
	Technical Elective	4
Total		14

<i>Spring Term</i>		<i>Credit</i>
CSSE 489	Senior Research Project III or	4
CSSE 499	Senior Capstone Project III or	
CSSE 496	Senior Thesis III	
Free	Elective	4
Free	Elective	4
Total		12
Total credits required:		192

CSSE electives cannot include any of CSSE 372, 373, 375, 376, and 477.
Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.
HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or

MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.

- 2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
- 3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
- 4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
- 5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
- 6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 7. A total of 192 credits.

Area Minor in Computer Science

Advisor: Dr. Laxer

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

CSSE120 Introduction to Software Development
CSSE220 Object-Oriented Software Development
CSSE230 Data Structures and Algorithm Analysis
16 additional credits of computer science courses numbered above 200.
None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories
2. use economic theory to define, analyze and solve a wide range of problems.
3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.
4. communicate complex economics topics in both oral and written form.
5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
HSS	or	
	Elective	
Physical or Life Science		4
Total		14
Winter Term		Credit
MA 112	Calculus II	5
CSSE 120	Introduction to	4
Software Development		
Physical or Life Science		4
RH 131	Rhetoric and Composition	4
HSS	or	
	Elective	
Total		17
Spring Term		Credit
MA 113	Calculus III	5

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
Economics Elective		4
*HSS Elective		4
Physical or Life Science		4
Total		16
Winter Term		Credit
MA 212	Matrix Algebra and	4
Systems		
of Differential Equations		
Economics Elective		4
*HSS Elective		4
Physical or Life Science		4
Total		16
Spring Term		Credit
MA 381	Introduction to Probability	4
with Applications		
or	to Statistics	

Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer
Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second
Major Only)

Computational Science Major (CPLS)
(Second Major Only)

International Studies Major (IS) (Second
Major Only)

Army ROTC (Military)

Pre-Professional Programs

SV 151	Principles of Economics	4	MA 223	Engineering Statistics	4
	Physical or Life Science	4		Economics Elective	4
	*HSS Elective	4		*HSS Elective	4
	Total	17		Physical or Life Science	4
			Total		16

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

1. 20 credits of required Economics courses:
SV151 Principles of Economics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX496 Seminar for HSS Senior Projects
XX497 Directed Study for HSS Senior Project
2. 24 additional credits in Economics electives.
3. 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA211, 212 Differential Equations , and Matrix Algebra and Systems of Differential Equations
MA223 Engineering Statistics I or
MA381 Introduction to Probability
4. 12 additional credits in Mathematics other than MA351-356.
5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
7. 4 credits in Engineering Management
8. 4 credits in Computer Science: CSSE 120
9. CLSK 100 (1 credit) and SV 200 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
SV 200	1
TOTAL	193



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;

2. Function independently and in leadership positions within multidisciplinary teams;

3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;

4. Adapt and independently extend their learning to excel in fields about which they are passionate;

5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.

EE student outcomes

At the time of graduation, students will have demonstrated:

- an ability to apply knowledge of mathematics, science, and engineering

• an ability to design and conduct experiments, as well as to analyze and interpret data

• an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

• an ability to function on multidisciplinary teams

• an ability to identify, formulate, and solve engineering problems

• an understanding of professional and ethical responsibility

• an ability to communicate effectively

• the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

• a recognition of the need for, and an ability to engage in life-long learning

• a knowledge of contemporary issues

• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

ELECTRICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
PH 111	Physics I	4	MA 211	Differential Equations	4

- Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs

MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
Total		16

<i>Winter Term</i>		<i>Credit</i>
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Introduction to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
Total		17

<i>Spring Term</i>		<i>Credit</i>
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
Total		17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
ECE 380	Discrete-Time Signals and Systems	4
ECE 351	Analog Electronics	4
ECE 340	Electromagnetic Fields	4
RH 330	Technical and Professional Communication	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
ECE 320	Linear Control Systems	4
HSS	Elective	4
ECE 341	Electromagnetic Waves	4
	Math/Science Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
ECE 310	Communications Systems	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
Total		15

CHEM 111	General Chemistry	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 370	Power & Energy Systems or	4
ECE 371	Sustainable Energy Systems	
ECE 250	Electronics Device Modeling	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
ECE 460	Engineering Design I	3
	Math Elective	4
	Area Elective	4
HSS	Elective	4
Total		15

<i>Winter Term</i>		<i>Credit</i>
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
Total		18
Total credits required:		194

AREA ELECTIVES

At least two of the three Area Electives must bear an ECE prefix at the 400 level or above
At most one of the Area Electives can bear an ECE or CSSE prefix at the 300 level or above
Exceptions to this requirement may be granted by the ECE Department Head

TECHNICAL ELECTIVE - Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering as a free electives or technical elective. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

ELECTRICAL ENGINEERING CORE COURSES

Course Number	Course Title	Credits
ECE160	Engineering Practice	2
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE230	Introduction to Microcontrollers	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE 371	Power & Energy Systems or Sustainable Energy Systems	3
ECE380	Discrete-Time Signals and Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

SECOND MAJOR IN ELECTRICAL ENGINEERING

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Title	Credits
ECE180	Introduction to Signal Processing	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Circuits Systems	4
ECE230	Introduction to Microcontrollers	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE370	Power & Energy Systems	4
	or	

ECE371	Sustainable Energy Systems	
ECE380	Discrete-Time Signals and Systems	4
MA381	Introduction to Probability with Applications to Statistics	4
Total		64

AREA MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE160, ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Example Area Minor for Engineering Physics and Optical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE180	Intro to Signal Processing	4	ECE204	AC Circuits	4
ECE204	AC Circuits	4	ECE230	Intro to Embedded Systems	4
ECE205	Circuits and Systems	4	ECE233	Intro to Digital Systems	4
ECE300	Continuous Time Signals and Systems	4	ECE250	Electronic Device Modeling	4
ECE380	Discrete-Time Signals and Systems	4	ECE351	Analog Electronics	4
or					
ECE310	or Communication Systems				

Examples Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Intro to Signal Processing	4
ECE230	Intro to Embedded Systems	4	ECE205	Circuits and Systems	4
ECE233	Intro to Digital Systems	4	ECE230	Intro to Embedded Systems	4
ECE250	Electronic Device Modeling	4	ECE233	Intro to Digital Systems	4
ECE332	Computer Architecture II	4	ECE332	Computer Architecture II	4

Examples Area Minor for Mechanical Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE203	DC Circuits	4
or	or		or	or	
ES203	Electrical Systems		ES203	Electrical Systems	
ECE204	AC Circuits	4	ECE180	Intro to Signal Processing	4
Required			ECE204	AC Circuits	4
ECE370	Power & Energy Systems	4	ECE233	Intro to Digital Systems	4
ECE371	Sustainable Energy	4	ECE250	Electronic Device Modeling	4

	Systems		ECE351	Analog Electronics	4
ECE470	Power Systems I	4			
ECE471	Industrial Power Systems	4			

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

ENHANCED STUDY IN COMMUNICATION SYSTEMS

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 312 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Continuous-Time Signals Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Circuits and Systems
- ECE300 Continuous-Time Signals Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

ENHANCED STUDY IN POWER SYSTEMS

Power Certificate

Take all of the following courses:

- ECE 473 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

ECE 310 Communication Systems
OE 393 Fiber Optics and Applications
OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 312 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

EP Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will contribute to society locally, nationally or globally
- Our graduates will collaborate within their organization; and be active in research and development in a relevant area of science and technology.
- Our graduates will continue to develop professionally.

EP Student Learning Outcomes

- Outcome A:

Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
- Outcome B1:

Interpreting Data: Ability to interpret graphical, numerical, and textual data.
- Outcome B2:

System Level Modeling: Ability to model components and system level engineering problems.
- Outcome B3:

Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.

Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

- Outcome C:

Design: Ability to design a product or process to satisfy client's needs subject to constraints.
- Outcome D:

Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
- Outcome E:

Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
- Outcome F:

Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
- Outcome G:

Communication: Ability to communicate effectively in oral, written and visual forms.
- Outcome H:

Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Outcome I:

Life Long Learning: A facility for independent learning and continued professional development.

ENGINEERING PHYSICS (Micro-Nano)

Freshman Year

Fall Term		Credit
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graphical Communications	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
OE 172	Optics in Technology*	2
EM 103	Introduction to Design**	2
Total		17*

Junior Year

Fall Term		Credit
PH 316	Electric and Magnetic Fields	4
ENG	200 Level Engineering Elective	4
PH 405	Semiconductor Materials and Applications	4
MA 223	Engineering Statistics I	4
Total		16

Winter Term		Credit
HSS	Elective	4
PH 317	Electromagnetism	4
RH 330	Technical and Professional Communication.	4

Sophomore Year

Fall Term		Credit
ECE 203	DC Circuits	4
PH 235	Many Particle Physics	4
MA 211	Differential Equations	4
SEM	Sci, Engr or Math Elective	4
Total		16

Winter Term		Credit
EP 280	Intro to Nano Engineering	4
PH 255	Foundations of Modern Physics	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 204	AC Circuits	4
Total		16

Spring Term		Credit
EP 380	Nano Technology Entrepreneurship and Ethics	4
OE 295	Optical Systems	4
SV 151	Principles of Economics	4
EM 121	Statics	4
Total		16

Senior Year

Fall Term		Credit
EP 416	Engineering Physics Project II	4
EP 407	Semiconductor Fabrication and Characterization	4
EP 411	Advanced MEMS	4
HSS	Elective	4
Total		16

Winter Term		Credit
EP 417	Engineering Physics Project III	4
ENG	300/400 Engineering Elective	4
HSS	Elective	4
PH 401	Intro Quantum Mechanics	4

EP 406	Semiconductor Devices and Fabrication	4	Total	16
Total		16	<i>Spring Term</i>	<i>Credit</i>
<i>Spring Term</i>		<i>Credit</i>	HSS	Elective
PH 327	Thermodynamics & Stat Mech	4	HSS	Elective
EP 410	Intro to MEMS	4	ENG	Engineering Elective
EP 415	Engineering Physics Project I	4	Free	Free Elective
HSS	Elective	4	Total	16
Total		16	Total credits required:	194

*If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

Subjects	#Classes	Hours
Physics(PH)	10	40
Math(MA)	6	27
Chemistry(CHEM)	2	8
ME	1	4
EM	3	8
CLSK	1	1
Electrical Engineering	2	8
Optical Engineering (OE)	2	6
HSS	9	36
Engineering Physics (EP)	6	24
Engineering Physics Project(EP)	3	12
Elective(SEM, Eng. and Free)	5	20
Total	50	194

SUMMARY OF GRADUATION REQUIREMENTS FOR ENGINEERING PHYSICS

- 1. All the courses listed above by the number.
- 2. The program must be approved by the EP advisor.
- 3. A list of the engineering electives is provided.
- 4. SEM (Science, Engineering, Math) electives are courses that need to be taken at the 200 level (CHEM115 is allowed) or above in the physics, chemistry, math, or biology programs.
- 5. A free electives is any course in engineering, science, humanities, military science, or air science.

Classes by Subjects	Hours
Physics Coursework*	40
Chemistry and Mathematics Coursework**	35
Humanities and Social Science(Standard requirement)	36
EM, ME, CLSK Courses	13
Electrical Engineering Courses	8
Optical Engineering Courses	6
EP Courses	24
EP Projects	12
Engineering Electives	8
SEM and Free Electives	8
Total	193

Foundation Physics Classes

Course	Description	Hours
PH 235	Many Particle Physics	4
PH 255	Modern Physics	4

PH 316	Electric & Magnetic Fields	4
PH 317	Electromagnetism	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Introduction to Quantum Mechanics	4
Total		24

General Foundation Classes

Course	Description	Hours
PH 111	Physics I	4
PH 112	Physics II	4
PH 113	Physics III	4
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 223	Engineering Statistics	4
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
Total		47

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	2
OE 172	Lasers and Fiber Optics	2
EM 121	Statics I	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
EP 280	Introduction to Nano-engineering	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
OE 295	Photonic Devices and Systems	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
EP 411	Advance Topics in MEMS	4
EP 407	Semiconductor Fabrication % Characterization	4
	Engineering Elective	12
ME123	Computer Applications	4
Total		68

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	4
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Approved Engineering 200-Level Electives (4 credit hours required)

- ECE 205 Circuits and Systems
- ES 201 Conservation and Accounting Principles
- ES 202 Fluid and Thermal Systems
- EM 204 Statics II
- OE 280 Geometric Optics
- EP 290 Directed Study
- EP 490 Directed Study

Approved Engineering Electives

- OE 360 Optical Materials
- OE 393 Fiber Optics
- OE 437 Introduction to Image Processing
- OE 450 Laser Systems and Applications
- OE 495 Optical Metrology
- EP 330 Materials Failure
- EP 470 Special Topics in Engineering Physics
- EP 490 Directed Study
- CHE 315 Materials Science and Engineering
- ME 328 Materials Engineering
- ME 417 Advanced materials Engineering
- ME 422 Finite Elements for Engineering Applications
- EM 403 Advanced Mechanics of Materials
- ECE 351 Analog Electronics
- ECE 250 Electronic Device Modeling



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

International Computer Science

INTERNATIONAL COMPUTER SCIENCE

The International Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The international computer science curriculum is designed to prepare students for multiple careers in a rapidly changing, global environment. The program's courses emphasize fundamental concepts and techniques that will last longer than present technology.

International computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer systems, computer architecture, programming languages, operating systems, and software engineering. Advanced courses in theory of computation, computer networks, distributed systems, security, and real time systems add depth to the degree program. A three-term senior thesis provides students the opportunity to research in depth an area of computer science that is of interest to them under the mentorship of a faculty member. Majors also complete important courses in closely related fields, e.g., discrete mathematics and probability and statistics, as well as study a foreign language. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Five free electives allow students to tailor their undergraduate education to their specific goals and pursue topics of interest to them. Students may choose to do advanced elective work in computer science and software engineering and/or in the humanities and social sciences, and/or pursue a minor or double major in another discipline.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Department laboratories provide docking stations and large screen monitors for students to attach their laptops to. International computer science majors have unlimited access to the department's laboratories.

The department has active programming teams that compete in the ACM Programming Contest and the Collegiate Cyber Defense Competition. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman; it sponsors several seminars throughout the year.

International Computer Science Program Educational Objectives

Graduates from the international computer science program will be prepared for many types of careers in the

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

computing industry and prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman international computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

International Computer Science Student Outcomes

By the time students graduate with an international computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools.
2. Anticipate complexities and problems involved in the development of large software systems.
3. Analyze requirements, design software that satisfies those requirements, and implement that software.
4. Analyze problems using ideas of problem complexity, models of computation, and decidability.
5. Design algorithms using a variety of paradigms.
6. Analyze algorithms in terms of correctness as well as time and space efficiency.
7. Communicate effectively, both verbally and in writing.
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry.
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering.
10. Collaborate effectively in small teams.
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering.
12. Explain the impact of globalization on computing and software engineering.
13. Recognize the need for, and engage in, lifelong learning.
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software	4
	Development	
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term		Credit
CSSE 220	Object-Oriented Software	4
	Development	
MA 112	Calculus II	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
GE 111	German Language and	4
	Culture I	
MA 212	Matrix Algebra and Systems	4
	of Differential Equations	
MA 275	Discrete and Combinatorial	4
	Algebra I	
Total		16

Winter Term		Credit
CSSE 230	Data Structures and	4
	Algorithm Analysis	
GE 112	German Language and	4
	Culture II	
MA 375	Discrete and Combinatorial	4
	Algebra II	

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

Tech	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Language Concepts	4
GE 113	German Language and Culture III	4
MA 381	Introduction to Probability with Statistical Applications	4
RH 330	Technical and Professional Communication	4
Total		16

Junior Year (at Hochschule Ulm, Germany)

<i>First Semester</i>		<i>Credit</i>
VSYS	Distributed Systems & IT Security	4
ECHT	Real-time Systems	4
IPRO	Project Management & Integrated Project I	4
SEM	Seminar	4
	Technical German	4
Free	Elective	4
Total		24

<i>Second Semester</i>		<i>Credit</i>
COMPA	Computer Architecture	4
BSYS	Operating Systems	4
DABA	Databases	4
IPRO	Project Management & Integrated Project II	4
RNET	Computer Networks	4
	Humanities Course	4
Total		24

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 494	Senior Thesis I	4
ECE 332	Computer Architecture II	4
Free	Elective	4
Free	Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 495	Senior Thesis II	4
CSSE/MA 474	Theory of Computation	4
Tech	Elective	4
Free	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 496	Senior Thesis III	4
CSSE/MA 473	Design and Analysis of Algorithms	4
Free	Elective	4
Total		12
Total Credits Required		192

Summary of graduation requirements for the international computer science major

HSS electives must be distributed as required by HSS. Science elective is any CHEM, PH, GEOL, or BIO course(s) totaling at least 4 credits.

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number, symbol, or name in the schedule of courses above: CSSE 120, CSSE 132, CSSE 220, CSSE 230, CSSE 304, CSSE or MA 473, CSSE or MA 474, and CSSE 494-6; MA 111, MA 112, MA 113, MA 212, MA 275, MA 375, MA 381; ECE 332; PH 111, PH 112; CHEM 111; RH 131, RH 330; GE 111, GE 112, GE 113; CLSK 100; BSYS, COMPA, DABA, ECHT, IPRO, RNET, SEM, VSYS, Technical German.
- 2. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the international computer science major.
- 3. Eight additional credits of technical electives. Consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
- 4. Twelve credits of additional courses offered by the Department of Humanities and Social Sciences and/or

appropriate humanities or social science courses offered at Hochschule Ulm. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences at Rose-Hulman.

- 5. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 6. A total of 192 credits.



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Programs of Study

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Mathematics

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

PROGRAM GOALS AND OBJECTIVES

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

DEGREE REQUIREMENTS

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core	12 hrs.
Three courses selected per the list below. Students completing the Continuous Applied	

Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry, mathematics modeling or application, or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- MA 493 and MA 494 must be taken in seperate terms.
- The requirement of MA 491-492 may be fulfilled through some project experience (such as an internship) and another 300-level or above mathematics course (4 hours), as approved by the project advisor. The course substitution procedure must be used.
- The project must involve work done by the student(s) to solve a problem presented by

an external sponsor or a problem with a substantial mathematical modeling, application and/or computational content. The written project submission must be approved by the advisor and/or sponsor, and must be presented publicly to the department.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team).
- The approved written thesis must be submitted to the department for archiving and must be publicly presented to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.

Total hours required for graduation	195 hrs.
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* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
BIO 101 — Essential Biology (or higher-level BIO course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	
*** 200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.	24 hrs.
**** CLSK 100 — College and Life Skills	1 hr.
MA 200 - Career Preparation (primary major only)	1 hr.

SUGGESTED SCHEDULE

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math

elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended science schedule of six science courses starts with PH 111. If CHEM 111 is required in the fall quarter because of a double major or minor, then the alternate science sequence may be completed by taking the second science course in each place where a choice is given. Two science courses are to be taken in the winter quarter of freshman year.

MATHEMATICS

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
	or	
CHEM 111	General Chemistry I	4
RH 131	Rhetoric and Composition	
	or	4
HSS	Elective	
CLSK 100	College and Life Skills	1
CSSE 120	Introduction to Software Development	4
Total		18

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
	or	
PH 111	Physics I	4
CHEM 111	General Chemistry I	
	or	4
BIO 101	Essential Biology (or higher level BIO course)	
HSS	Elective	4
	or	
RH 131	Rhetoric Composition	17
Total		

Spring Term		Credit
MA 113	Calculus III	5
PH 113	Physics III	4
	or	
PH 112	Physics II	2
MA 190	Contemporary Mathematics Problems	
HSS	Elective	4
Total		15

Junior Year

Fall Term		Credit
MA	Elective	4
	Technical Elective	4
	Technical Elective	4
HSS	Elective	4
	or	
RH 330	Technical and Professional Communication	4
Total		16

Winter Term		Credit
MA 366	Functions of a Real Variable	4

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
MA 275	Disc. & Comb. Algebra I	4
BIO 101	Essential Biology (or higher level BIO course)	4
	or	
PH 113	Physics III	4
*CSSE 220	Object-Oriented Software Development	
Total		16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Science Elective	4
	Technical Elective	4
HSS	Elective	1
**MA 200	Career Preparation	
Total		17

Spring Term		Credit
MA 381	Introduction to Probability	4
MA 371	Linear Algebra I	4
	Technical Elective	4
HSS	Elective	4
Total		16

Senior Year

Fall Term		Credit
MA 491	Intro to Math Modeling (2 hours)	4
MA 492	Senior Project I (2 hrs.)	4
	or	
MA 496	Senior Thesis I (4 hrs.)	4
	Free Elective	
	Free Elective	4
HSS	HSS	
Total		16

Winter Term		Credit
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MA	Elective	4
	Technical Elective	
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
	Total	16

<i>Spring Term</i>		<i>Credit</i>
MA	Elective	4
MA	Elective	4
	Technical Elective	4
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
	Total	16

MA 493	Senior Project II (2 hrs.)	
	or	2
MA 497	Senior Thesis II (2 hrs.)	
MA	Elective	4
	Free Elective	4
	Free Elective	4
	Free Elective	4
	Total	18

<i>Spring Term</i>		<i>Credit</i>
MA 494	Senior Project III (2 hrs.)	
	or	2
MA 498	Senior Thesis III (2 hrs.)	
MA	Elective	4
	Free Elective	4
	Free Elective	4
	Total	14

Total credits required: 195

Notes:

- *MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework
- **MA 200 - Career Preparation - may be taken in the winter quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- **Math Elective:** A course either required by the concentration or a true math elective.
- **Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- **Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- **Free Elective:** Any course.

Computational Science Major (CPLS) (Second Major Only)

Computational methods are widely employed in science and engineering for simulation, experimentation, analysis, and design. In many areas the use of high-performance computing is essential. The Computational Science major provides Rose-Hulman students with the opportunity to add to their primary major a second major that increases their knowledge and skill in applied scientific and engineering computation.

Requirements for a second major in Computational Science (71 credit hours)

The second major in Computational Science is open to all students. It requires 71 credit hours, including a 55 credit hour core and a 16 credit hour specialization. The courses used to satisfy the requirements in the Advanced Core may not be counted toward any other major or minor. All Computational Science programs of study are subject to approval by the Chair of the Computational Science Steering Committee

I. Computational Science Core (55 credit hours)

Fundamentals (35 credit hours)

- MA 111, 112, 113 Calculus I, II, III
- MA 211 Differential Equations
- MA 212 Matrix Algebra and Systems of Differential Equations
- CSSE 120 (1) Introduction to Software Development, or any of BE 100, CE 110, CHE 110 (plus 2

cr.), ME 123

- CSSE 132 or ECE130 Introduction to Computer Systems, Introduction to Logic Design
- MA 332 (2) Introduction to Computational Science, or any of CE 310 (plus 2 cr.) CHE 310, ME 323 (plus 2 Credits)

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any upper-level computational science course (see list below)

List of Advanced Electives

- BE 510 Biomedical Signal and Image Processing
- CHE 521 Advanced Chemical Engineering Computation
- CSSE 304 Programming Language Concepts
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- ECE 582/PH 537 Advanced Image Processing
- EMGT 526 Technology Forecasting
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 348 Continuous Optimization
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis
- MA 435 Finite Difference Methods
- MA 439 Mathematical Methods of Image Processing
- MA 444 Deterministic Models in Operations Research
- MA 446 Combinatorial Optimization
- MA 490 Mathematical Biology
- ME 422 Finite Element Methods for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Elements Analysis
- Other courses may be counted as advanced electives upon approval by the Chair of Computational Science.

II. Area of Concentration (16 credit hours): Each student must complete 16 credit hours in an area of concentration within Computational Science. Courses used to satisfy the core requirements may not be used to satisfy the area of concentration requirements.

Computational Methods

- MA 371 or MA 373 Linear Algebra I, Applied Linear Algebra for Engineers
- MA 433 Numerical Analysis
- Eight credit hours chosen from CSSE 304, CSSE/MA 473, MA 348, MA 386, MA 434, MA 435, MA439, MA 444, MA 446, MA 485, ME 422

Computational Mechanics

- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- ME 401 Foundations of Fluid Mechanics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Element Analysis

Computational Signals and Image Processing

- ECE 380 Discrete-Time Signals and Systems
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- MA 439 Mathematical Methods of Image Processing

Computational Physics and Chemistry

- CHEM 361 Physical Chemistry I
- CHEM 362 Physical Chemistry II
- CHEM 363 Quantum Chemistry & Molecular Spectroscopy
- OE 570 Nanomedicine
- PH 540 Computer Physics

Computational Biomedics

- BE 482/MA 482 Bioengineering Statistics
- BE 535/OE 535 Biomedical Optics
- BE 541/ECE 597 Medical Imaging
- MA 490-01 Mathematical Biology 1
- MA 490-02 Mathematical Biology 2

AREA MINOR IN MATHEMATICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

AREA MINOR IN COMPUTATIONAL SCIENCE

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics

- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the major.
- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

AREA MINOR IN STATISTICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- **Globally required mathematics courses**
MA 111 Calculus I
MA 112 Calculus II
MA 113 Calculus III
MA 212 Differential Equations
- **Required Introductory Statistics/Probability Courses**
MA 381 Introduction to Probability with Applications to Statistics,
One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is taken before MA223/MA382 the student will be strongly recommended to take MA382.
- **Required Second Statistics Course**
One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics
- **Electives**
3 courses (12 credits) selected from the following list, at least two of which must be starred. Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.

MA 385* Quality Methods
MA 386* Statistical Programming
MA 387* Statistical Methods in Six Sigma
MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers
MA 445 Stochastic Models in Operations Research
MA 481* Mathematical Statistics
MA 485* Regression and Time Series Analysis
MA 487* Design of Experiments
MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students
- Only MA111, MA112, MA113, MA212 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.



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Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Mechanical Engineering

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Design Processes and Methodology.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 20 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

Vision: To graduate the best baccalaureate mechanical engineers.

- | |
|--------------------------------|
| Biological Sciences |
| Biology |
| Biochemistry |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| International Computer Science |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- | |
|---|
| Air Force ROTC (Military) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS)
(Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Army ROTC (Military) |
| Pre-Professional Programs |

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

- a. *an ability to apply knowledge of mathematics, science, and engineering*
- b. *an ability to design and conduct experiments, as well as to analyze and interpret data*
- c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
- d. *an ability to function on multi-disciplinary teams*
- e. *an ability to identify, formulate, and solve engineering problems*
- f. *an understanding of professional and ethical responsibility*
- g. *an ability to communicate effectively*
- h. *the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
- i. *a recognition of the need for, and an ability to engage in life-long learning*
- j. *a knowledge of contemporary issues*
- k. *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*

Area Minor*** in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

ME 301 Thermodynamics II
CHE 303 Chem. Engineering Thermodynamics
ME 302 Heat Transfer
CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems

- ME 407 Power Plants**
- ME 408 Renewable Energy
- ME 409 Air Conditioning*
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems**
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundation of Fluid Mechanics
- ME 402 Advanced Heat Transfer*
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 450 Combustion
- ME 501 Advanced Thermodynamics**
- ME 502 Topics in Heat Transfer*
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

**Requires one of the thermodynamics prerequisites from section 2 above.
* Requires one of the heat transfer prerequisites from section 2 above.
*** ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may include special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

- ECE/ME 497 Introduction to Model-Based System Design
- ECE/ME 497 Advanced Model Based-System Design

Elective Courses

- CHEM 470 Combustion Chemistry

- ECE 320 Linear Control Systems
or
ME 406 Control Systems

- ECE 420 Nonlinear Control Systems
or
ME 506 Advanced Control Systems

- ECE 370 Machines & Power
- ECE 410 Communication Networks
- ECE 452 Power Electronics

ME 408 Renewable Energy
ME 410 Internal Combustion Engines
ME 411 Propulsion Systems
ME 422 Finite Elements for Engineering Applications
ME 427 Introduction to Computational Fluid Dynamics
ME 450 Combustion

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

MA 336 Boundary Value Problems
ME 405 Theoretical Aerodynamics
ME 401 Foundation of Fluid Mechanics
ME 411 Propulsion Systems
ME 422 Intro to Finite Element Fundamentals
ME 426 Turbomachinery
ME 427 Introduction to Computational Fluid Dynamics
ME 461 Aerospace Design
ME 503 Viscous Flow
ME 510 Gas Dynamics
ME 512 Light Weight Structures
ME 522 Advanced Finite Element Analysis
PH 322 Celestial Mechanics

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

CE 561 or CHE 450 Air Pollution (cross-listed class)
CE 590 Climate Change Assessment
CHE 490 Energy and Environment
CHE 512 Petrochemical Processes
ECE 370 Power and Energy Systems
ECE 371 Industrial Power Systems
ME 407 Power Plants
ME 408 Renewable Energy

ME 450 Combustion
ME 501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

MA 385 Quality Methods
MA 487 Design of Experiments
MA 387 Statistical Methods in Six Sigma

Engineering Management List

EMGT 330 Introduction to Engineering Management
EMGT 427 Project Management
EMGT 520 Accounting for Technical Managers
EMGT 521 Financial Management in a Technical Environment
EMGT 522 Organizational Management
EMGT 523 Marketing Issues in a Technical Environment 4
EMGT 524 Production/Operations Management
EMGT 526 Technology Management and Forecasting
EMGT 527 Project Management
EMGT 531 Economics for Technical Managers
EMGT 532 Technical Entrepreneurship
EMGT 533 Intercultural Communication
EMGT 534 Management Science
EMGT 535 Strategies for Organizational Change
EMGT 586 Supply Chain Management
EMGT 587 Systems Engineering
EMGT 588 Quality Management I
EMGT 589 Manufacturing Systems

Humanities, Social Sciences List

GS 350 International Trade
GS 351 International Finance
IA 230 Fundamentals of Public Speaking
SV 151 Principles of Economics
SV 350 Managerial Accounting
SV 351 Managerial Economics
IA 352 Game Theory
SV 303 Business and Engineering Ethics
SV 304 Bioethics
SV 352 Money & Banking
SV 353 Industrial Organization
SV 354 Environmental Economics
SV 356 Corporate Finance
EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 588 Quality Management
- EMGT 589 Manufacturing Systems
- MA 385 Quality Methods
- ME 317 Design for Manufacturing
- ME 417 Advanced Materials Engineering
- ME 435 Robotics
- ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 450 Combustion
- ME 501 Advanced Thermodynamics
- ME 502 Topics in Heat Transfer
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the **Thermal Fluid Systems**list and at least two courses are taken from the **Thermal Fluid Sciences**list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET,www.abet.org

MECHANICAL ENIGNEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
RH 131	Rhetoric and Composition split fall or winter with Elective	4
HSS		
Total		16
Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
EM 121	Statics and Mechanics of Materials I	4
RH 131	Rhetoric and Composition split fall or winter with Elective	4
HSS		
Total		17
Spring Term		Credit
MA 113	Calculus III	5
PH 113	Physics III	4
EM 103	Introduction to Design	2
ME 123	Computer Applications I	4
Total		15

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4
ES 201	Conservation & Accounting Principles	4
ES 203	Electrical Systems	4
HSS	Elective	4
Total		16
Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ES 202	Fluid & Thermal Systems	3
ES 204	Mechanical Systems	3
CHEM 111	General Chemistry I	4
HSS	Elective	4
Total		18
Spring Term		Credit
MA 223	Statistics for Engineers	4
ES 205	Analysis & Design of Engineering Systems	4
CHEM 113	General Chemistry II	4
HSS	Elective	4
Total		16

Junior Year

Fall Term		Credit
ME 301	Thermodynamics II	4
EM 204	Statics & Mechanics of Materials	4
ME406	Control Systems	4
or	or	
EM 406	Vibration Analysis	
*Free	Elective	4
Total		16

Winter Term		Credit
ME 317	Design for Manufacturing	3
ME 321	Measurement Systems	4
	split winter or spring with	
ME 323	Computer Applications II	(2)
Science	Elective	4
ME 328	Materials Engineering	4
RH 330	Technical Communications	4
	split winter or spring with	
HSS	Elective	
Total		(17)
		or 15

Spring Term		Credit
ME 302	Heat Transfer	4
ME 323	Computer Applications II	2
Science	Elective	4
	split winter or spring with	
ME 321	Measurement Systems	
ME 470	Engineering Design Proc & Method	3
	split Jr. spring or Sr. fall with	(4)
	Machine Component Design	
HSS	Elective	4
	split winter or spring with	
RH 330	Technical Communications	
Total		(16)
		or 17

Senior Year

Fall Term		Credit
ME 430	Mechatronic Systems	4
	split fall or winter with	
ME 421	M.E. Lab and *Tech Elective	(2+4)
*Tech	Elective	4
ME 480	Machine Component Design	4
	split Jr. spring or Sr. fall with	
ME 470	Engineering Design Proc & Method	(3)
*Tech	Elective	4
Total		(17)
		or 16

Winter Term		Credit
ME 471	Capstone Design I	(3) 3
ME 421	M.E. Lab and *Tech Elective	2+4
	split fall or winter with	
ME 430	Mechatronic Systems	(4)
HSS	Elective	4
*Free	Elective	4
Total		(15)
		or 17

Spring Term		Credit
ME 472	Capstone Design II	3
*Tech	Elective	4
*Tech	Elective	4
HSS	Elective	4
Total		15
Total credits required:		194

*28 credit hours. in electives composed of 20 cr. hrs. in technical electives and 8 cr. hrs. in free electives.

*A **technical elective** is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A **science elective** is any course in applied biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.



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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>

OE Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will make a meaningful impact on society.
- Our graduates will behave ethically and act as responsible members of the engineering and science community.
- Our graduates will continue to develop professionally

OE Student Learning Outcomes

Outcome A: An ability to apply knowledge of mathematics, science, and engineering

Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Air Force ROTC (Military)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Army ROTC (Military)
Pre-Professional Programs

- Demonstrate competency in applying knowledge of mathematics (such as multivariable calculus, differential equations, linear algebra, complex variables, and probability and statistics), physics and chemistry
- Demonstrate competency in applying basic engineering science topics with common themes among engineering disciplines
- Demonstrate competency in applying theoretical and experimental knowledge in geometrical optics, physical optics, optical materials and devices to modeling, analysis and design of optical/photonics devices and systems

Outcome B:

An ability to design and conduct experiments, as well as to analyze and interpret data

- Identify the problem and determine what data need to be collected.
- Apply safe laboratory practices
- Select appropriate measurement techniques to collect the data.
- Demonstrate the ability to use laboratory equipment for measurement.
- Use appropriate statistical and analytical procedures to estimate uncertainties and interpret results
- Be able to recognize the necessity to use graphical and numerical analysis
- Extract trends and demonstrate their importance from numerical data, graphs, and text.
- Draw conclusions

Outcome C:

An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

- Elicit customer needs and define realistic constraints
- Identify viable alternatives in design and make an informed selection.
- Break down a system/process to its fundamental elements and components.
- Carry out design using appropriate tools.
- Incorporate economic analysis and analyze cost in design.
- Apply appropriate engineering standards.
- Deliver a functional prototype that meets customer needs.
- Document project work and give an oral and formal written report.

Outcome D:

An ability to function on multidisciplinary teams

- Share responsibilities and team duties by taking on different roles when applicable.
- Set milestones for the project.
- Discern feasible solutions.
- Develop a strategy for action.
- Meet objectives on schedule.
- Document work.
- Build consensus.

Outcome E:

An ability to identify, formulate, and solve engineering problems

- Identify, inspect, and define problems.
- Understand the basic principles and fundamental concepts required to solve problems
- Research and gather information.
- Use correct data, tools and adequate assumptions to solve problems.
- Demonstrate an awareness of multiple possible solutions.
- Develop criteria for evaluation of solutions.

Outcome F:

An understanding of professional and ethical responsibility

- Demonstrate knowledge of the Code of Ethics for Optical Engineers
- Evaluate the ethical dimensions of professional practice.
- Practice responsible decision making.

Outcome G:

An ability to communicate effectively

- Identify the technical knowledge and information needs of the audience.
- Provide technical content that is factually correct, supported with evidence, explained with sufficient detail, and properly documented.
- Summarize the graphical, numerical, and textual information in memos and reports.
- Submit work that is free of errors in spelling, punctuation, grammar, and usage.

Outcome H: The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

- Show an awareness of the impact of technology on culture and the environment and vice versa.

Outcome I: A recognition of the need for, and an ability to engage in life-long learning

- Demonstrate the ability to independently find and use technical information
- Demonstrate awareness of the current trend of optics/photonics technology by participating in exchange programs, internships, presentations or professional society activities.

Outcome J: A knowledge of contemporary issues

- Be knowledgeable of contemporary issues related to engineering practice

Outcome K: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- Design, construct, and align optical systems using light sources, optical components, mounts, and detection systems
- Use basic programming (e.g. Matlab or C+) for engineering practice.
- Use appropriate software tools for modeling optical devices and systems (e.g. Code V, Zemax, Light Tools)
- Use appropriate software tools for data analysis and presentation

The optical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

OPTICAL ENGINEERING

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graph Comm	2
Total		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4
Total		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
OE 172	Lasers and Fiber Optics *	2
EM 103	Intro Eng. Design	2
Total		17

Sophomore Year

Fall Term		Credit
PH 235	Many-Part Physics	4
PH 292	Physical Optics	4
MA 211	Differential Equations	4
ECE 203	DC Circuits	4
Total		16

Winter Term		Credit
ECE 204	AC Circuits	4
PH 255	Fnd. of Mod. Phys.	4
MA 212	Matrix Algebra & Sys of Diff Equat	4
OE 280	Geometrical Optics	4
Total		16

Spring Term		Credit
OE 295	Photonic Devices & Systems	4
SV 151	Principles of Economics	4
MA 223	Engineering Statistics	4
Free Elective		4
Total		16

Junior Year

Fall Term		Credit
OE 392	Linear Optical Systems	4
OE 395	Opto-Mech & Optical Eng Lab	4
PH 316	Elec & Mag Fields	4
HSS	Elective	4
Total		16

Winter Term		Credit
OE 393 or OE 360	Fiber Optics & Applications or Optical Materials	4
RH 330	Tech & Prof Communications	4
HSS	Elective	4
	Free Elective	4
Total		16

Spring Term		Credit
OE 415	Opt Eng Des I	4
OE 450	Laser Systems & Applications	4
HSS	Elective	4
	Engineering Elective**	4
Total		16

Senior Year

Fall Term		Credit
OE 416	Optical Eng Design II	4
OE 480	Optical System Design	4
PH 405	Semiconductor Materials & Appl	4
HSS	Elective	4
Total		16

Winter Term		Credit
OE 417	Optical Engineering Design III	4
OE 495	Optical Metrology	4
OE 393 or OE 360	Fiber Optics and Applications or Optical Materials	4
PH/OE/EP	Elective ***	4
Total		16

Spring Term		Credit
HSS	Elective	4
HSS	Elective	4
	Engineering Elective**	4
	Free Elective	4
Total		16

Total credits required: 194

*If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

**An engineering elective is any 200, 300, or 400-level course listed as OE, EP, ECE, ME, CE, BE, EM or ES.

***A PH/OE/EP elective is any 200, 300, or 400-level course listed as OE, EP or PH.

SUMMARY OF GRADUATION REQUIREMENTS FOR OPTICAL ENGINEERING

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects	Hours
Optics Coursework	46
Physics Coursework	20
Freshmen Physics, Chemistry and Mathematics Coursework	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous	25
Total	194

Physics Classes		
Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4

PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM111	Engineering Chemistry I	4
CHEM113	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
Total		17

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Leisher, Siahmakoun, Wagner, and Black.

Required Courses

Course	Hours	Course Description
OE 280	4	Geometrical Optics
PH 292	4	Physical Optics
OE 295	4	Photonic Devices and Systems

Plus at least two courses from one of the areas listed below:

Lens Design Area		
Course	Hours	Course Description
OE 360	4	Optical Materials
OE 415	4	Optical Engineering Design I
OE 480	4	Optical System Design
OE 490	4	Directed Research (4 Credits Only)
Photonics/Electro-optics Area		
Course	Hours	Course Description
OE 360	4	Optical Materials
OE 415	4	Optical Engineering Design I
OE 450	4	Laser Systems and Applications
OE 490	4	Directed Research (4 credits only)
OE 493	4	Fundamentals of Optical Fiber Communications
Image Processing Area		
Course	Hours	Course Description
OE 415	4	Optical Engineering Design I
OE 490	4	Directed Research (4 Credits Only)
OE 437/ECE 480	4	Introduction to Image Processing
PH 537/ECE 582	4	Advanced Image Processing

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)

Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203	4	DC Circuits
ECE 204	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman. All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

ECE 310 Communication Systems
OE 393 Fiber Optics and Applications
OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

ECE 380 Discrete Time & Continuous Systems
ECE 410 Communication Networks
ECE 414 Wireless Systems
OE 360 Optical Materials
OE 435 Biomedical Optics
OE 450 Laser Systems and Applications



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

PHYSICS

Freshman Year		
Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
RH 131 or HSS	Rhetoric and Comp or HSS Elective	4
EM 104	Graphical Communications	2
Total		16
Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 111	General Chemistry I	4
	Computing Elective*	2-4
Total		15 or 17
Spring Term		Credit

Sophomore Year		
Fall Term		Credit
	Free Elective†	4
PH 235	Many Particle Physics	4
MA 211	Differential Equations	4
PH 292	Physical Optics	4
Total		16
Winter Term		Credit
PH 255	Fund. of Modern Physics	4
HSS	Elective	4
	Technical Elective	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
Total		16
Spring Term		Credit
PH 314	Theoretical Mechanics I	4

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

PH 113	Physics III	4
MA 113	Calculus III	5
CHEM 113	General Chemistry II	4
HSS or RH131	HSS Elective or Rhetoric and Composition	4
Total		17

Junior Year

Fall Term		Credit
HSS	Elective	4
PH 316	Electric and Magnetic Fields	4
	Technical Elective†	4
PH 405	Semiconductor Materials and Applications	4
Total		16

Winter Term		Credit
PH 317	Electromagnetism	4
PH 401	Intro Quantum Mechanics	4
HSS	Elective	4
	Physics Elective†	4
Total		16

Spring Term		Credit
PH 325	Advanced Physics Lab I	4
HSS	Elective	4
OE 450	Laser Sys & App or	4
	Physics Elective†	
PH 327	Thermodynamics & Statistical Mechanics	4
Total		16

HSS	Elective	4
MA 371	Linear Algebra I	4
	Math Elective†	4
Total		16

Senior Year

Fall Term		Credit
Math	Elective†	4
	Technical Elective†	4
HSS	Elective	4
	Free Elective	4
Total		16

Winter Term		Credit
PH 425	Advanced Physics Lab II	4
HSS	Elective	4
	Technical Elective†	4
	Free Elective†	4
Total		16

Spring Term		Credit
	Technical Elective†	4
OE 450	Laser Sys & App or	4
	Physics Elective	
	Free Elective	4
	Physics Elective†	4
Total		16

Total credits required: 192

* Computing elective: 2 or 4 credit course on computing from the following course: BIO 100, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

SUMMARY OF GRADUATION REQUIREMENTS FOR PHYSICS MAJORS

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
6. Sixteen credits of free electives (cannot include ECE340).
7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
8. A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.

9. A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
PH 215	Introduction to Chaos	2
PH 231	Intro to Astronomy and Astrophysics	4
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 322	Celestial Mechanics and Solar	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
PH 407	Solid State Physics	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	Arranged
PH 470	Directed Research	Arranged
PH 480	Seminar	Arranged
PH 490	Directed Research	Arranged
PH 497+	Senior Thesis	Arranged
PH 498+	Senior Thesis	Arranged
PH 499+	Senior Thesis	Arranged
PH 512	Methods of Mathematical Physics	4
PH 514	Quantum Mechanics	4
PH 530	Advanced Acoustics	4
PH 537	Advanced Image Processing	4
PH 538	Introduction to Neural Networks	4

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year for a total number of 8 credit hours over the three quarter sequence. Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

**Math and Chemistry Courses:

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	
	Linear Algebra	4
MA 371	General Chemistry I	4

CHEM 111	General Chemistry II	4
CHEM 113		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus 12 credit hours from the following courses:

Course	Course Title	Hours
PH 270/470	Special Topics in Physics †	ARR
PH 290/490	Directed Research †	ARR
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4
PH 460	Directed Study †	ARR

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 290/490	Directed Research	2

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4
EP 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4

PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
OE 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer

Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

The software engineering program prepares its graduates for many types of careers in the computing industry as well as for graduate study in software engineering and in closely related disciplines. Within a few years after completing the software engineering degree program, our graduates will:

- Advance beyond their entry-level position to more responsible roles, or progress towards completion of advanced degree(s).
- Continue to keep pace with advancements in their disciplines, and develop professionally in response to changes in roles and responsibilities.
- Demonstrate that they can collaborate professionally within or outside of their disciplines at local, regional, national, or international levels.
- Contribute to the body of computing products, services, or knowledge.

Software Engineering Student Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The software engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

SOFTWARE ENGINEERING

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric & Composition	4
CLSK 100	College and Life Skills	1
Total		18

Winter Term	Credit
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Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
Total		16

CSSE 220	Object-Oriented Software Development	4
MA 112	Calculus II	5
PH 112	Physics II	4
HSS	Elective	4
Total		17

<i>Spring Term</i>		<i>Credit</i>
CSSE 132	Introduction to Computer Systems Design	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
Total		17

Junior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 371	Software Requirements Engineering	4
CSSE 372	Software Project Management	4
MA 381	Introduction to Probability with Statistical Applications	4
	Domain track course	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
HSS	Elective	4
	Domain track course	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 373	Formal Methods in Specification and Design	4
CSSE 375	Software Construction and Evolution	4
HSS	Elective	4
	Domain track course or free elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 230	Data Structures and Algorithm Analysis	4
CSSE 333	Database Systems	4
MA 375	Discrete & Combinatorial Algebra II	4
	Domain track course	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 304	Programming Lang. Con	4
CSSE 376	Software Quality Assurance	4
MA	Elective	4
RH 330	Technical and Professional Communication	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 477	Software Architecture	4
CSSE 497	Senior Capstone Project I	4
HSS	Elective	4
	Domain track course or free elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
CSSE 498	Senior Capstone Project II	4
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
Total		16

<i>Spring Term</i>		<i>Credit</i>
CSSE 499	Senior Capstone Project III	4
HSS	Elective	4
Free	Elective	4
Total		12

Total credits required: 192

Summary of graduation requirements for the software engineering major

To complete the major in software engineering a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE477, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA212, MA275, MA375, MA381; PH111, PH112, CHEM111; RH 131, RH330; CLSK100.
2. One additional CSSE elective course except CSSE 325, CSSE 473, CSSE 474, and CSSE 479. In addition, use of CSSE 49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.
3. A Domain Track set of courses. All of the courses for each of the [Domain Tracks](#) is listed on the CSSE website. That site also explains the procedures and deadlines by which a student must declare their Domain Track.

- 4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
- 5. Four credits of science electives, which can be any CHEM, GEOL, PH, or AB courses not already required for the software engineering major.
- 6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
- 7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

CSSE 120, Introduction to Software Development
CSSE 220, Object-Oriented Software Development
CSSE 230, Data Structures and Algorithm Analysis
CSSE 371, Software Requirements Engineering
CSSE 374, Software Design

Two additional courses in software engineering chosen from CSSE 372, 373, 375, 376, and 477.



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Incoming Freshman

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Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

ROSE-HULMAN

INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Air Force ROTC (Military)

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation-contact Air Force ROTC for more details.

SCHOLARSHIPS

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

Profession of Arms Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.

Communications Skills Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

General Military Courses

Freshman Year			Credit	Sophomore Year			Credit
AS 101	Found. of the US Air Force I	1		AS 201	Evol. of Air & Space Power I	2	
AS 101L	Leadership Laboratory	0		AS 201L	Leadership Laboratory	0	
AS 102	Found. of the US Air Force II	1		AS 202	Evol. of Air & Space Power II	2	
AS 102L	Leadership Laboratory	0		AS 202L	Leadership Laboratory	0	
AS 103	Found. of the US Air Force III	1		AS 203	Evol. of Air & Space Power III	2	
AS 103L	Leadership Laboratory	0		AS 203L	Leadership Laboratory	0	


Professional Officer Courses

Junior Year			Credit	Senior Year			Credit
AS 301	Air Force Lead. Studies I	4		AS 401	Nat.Sec.Aff./Prep. for Active Duty I	4	
AS 301L	Leadership Laboratory	0		AS 401L	Leadership Laboratory	0	
AS 302	Air Force Lead. StudiesII	4		AS 402	Nat.Sec.Aff./Prep. for Active Duty II	4	
AS 302L	Leadership Laboratory	0		AS 402L	Leadership Laboratory	0	
AS 303	Air Force Lead. Studies III	4		AS 403	Nat.Sec.Aff./Prep. for Active Duty III	4	
AS 303L	Leadership Laboratory	0		AS 403L	Leadership Laboratory	0	

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.

 **Rose-Hulman
Institute of Technology**
5500 Wabash Avenue
Terre Haute, IN 47803
812-877-1511



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Information For

Prospective Students	Faculty and Staff	Industry Partners
Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Humanities and Social Sciences

AREAS OF STUDY

[Global Studies](#) [Ideas and Art](#) [Society and Values](#) [Modern Languages](#)

MAJORS

- [Economics](#)
- [International Studies \(second major only\)](#)

GERMAN TECHNICAL TRANSLATION CERTIFICATE

MINORS

[Anthropology](#) [Art](#) [East Asian Studies](#) [Economics](#) [European Studies](#) [Geography](#)
[German](#) [History](#) [Japanese](#) [Language and Literature](#) [Latin American Studies](#) [Modern Languages](#) [Music](#) [Political Science](#) [Philosophy and Religion](#) [Psychology](#) [Spanish](#)
[Theatre and Drama](#)

Professors Bremmer, Carlson, Carvill, Casey, Chapman, Christ, Christensen, Dyer, Findley, Garcia, Gardner, Garner, Grose, Hartner, Hartnett, Heeter, Hirotani, House, Jern, Kim, Kukral, Letsinger, Livingston, Martland, Michel, Minster, Smith Roads, Summers, Taylor, Watt, and Williams.

MISSION STATEMENT

To enable our students to become creative, sophisticated thinkers, active citizens, and effective leaders in the global community, the department contributes to a broad liberal education, introducing students to a wide array of disciplines and traditions in the humanities and social sciences. In doing so, it provides learning experiences that, in addition to their intrinsic value, enrich a scientific and technical education.

Educational Objectives

Within the context of a liberal education, the department fosters in its students the desire and the ability to:

- think critically**, forming cogent, informed opinions, defining and solving problems with an awareness that societal processes are complex and interactive;
- communicate effectively** to diverse audiences, including those from other cultures and communities;
- succeed in a global context** by understanding and adapting to diverse cultures, alternative points of view, and the challenges of globalization;
- exhibit ethical and responsible leadership** as individuals, citizens, and professionals, committed to lifelong learning and achievement.

Disciplines

The HUMANITIES study what it means to be human within a contemporary or historical context. These

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art and Art History	Anthropology
English and Literature	Archaeology
Foreign Languages(German, Japanese, and Spanish)	Economics
History	Geography
Music	Political Science
Philosophy and Religion	Psychology
Theater	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- **Global Studies (GS prefix):** Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- **Ideas and Arts (IA prefix):** Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.
- **Society and Values (SV prefix):** Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communication are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communication is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general **lower level courses (100 and 200 level)** tend to be broad surveys of particular subject areas within disciplines. **Upper level courses (300 and 400 level)** are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General

- All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

- All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted free elective transfer credit, but are not exempted from RH 131.
- **EXEMPTION:** An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. Any HSS course may be substituted for RH 131 for exempted students.
 1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic

Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.

2. Has received grades of B or higher in all high school English courses.

- **INTERNATIONAL STUDENTS:** International students for whom English is not their native language will be required to take an assessment test to gauge their written, oral, and listening proficiency in English. The purpose of this testing is to ensure that all students have the proper communication skills to advance successfully through the challenging Rose-Hulman curriculum. Based on this assessment, some students will be required to take CLSK121 College English. Those students must successfully complete CLSK121 prior to taking RH131 Rhetoric and Composition.

3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.
 1. A minimum of two terms of the same language (or the equivalent thereof) must be completed in order to apply foreign language credits toward Humanities and Social Sciences requirements. If only SP111, JP111 or GE111 is completed, that course will not be allowed to satisfy an HSS requirement."
 2. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.
 3. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three thematic categories as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each thematic category in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
 4. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
 5. Students may not earn foreign language credit in their native languages.
 6. Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. Minors

- Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

HELP WITH REQUIREMENTS

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, Spanish or Theatre and Drama by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in

the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

<i>Minor</i>	<i>Adviser</i>
Anthropology	Paul Christensen
Art	Steve Letsinger
East Asian Studies	Tim Grose
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie
	Heeter
Geography	Michael A. Kukral
History	Samuel Martland
Japanese	Maki Hirotani
Language and Literature	Caroline Carvill
Music	David Chapman
Latin American Studies	Gustavo Garcia
Philosophy and Religion	Dan Hartner
Political Science	Terrence Casey
Psychology	Alan Jern
Spanish	John Gardner
Theatre and Drama	Terence Hartnett

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Introduction to East Asia 4R-OL-4C

Examines the changing political-economic and cultural orders in the East Asian region.

GS 130 Introduction to Sustainability 4R OL 4C Prereq: Admission to HERE Program or Consent of Instructor

Surveys the fundamentals of sustainability in scientific, technical, and social contexts. Introduces students to the history of environmentalism and sustainability, along with the basics of ecology, climate assessment, natural cycles, life cycle analysis, environmental economics, and other concepts.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 185 Introduction to Anthropology 4R-OL-4C

Examines human adaptation and diversity as well as the development and variety of economic, political, religious, family, gender and expressive institutions.

GS 188 Introduction to Sociology 4R-OL-4C

Examines the foundations of sociology, paying particular attention to how humans shape and give meaning to the world in which we live.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area,

from Afghanistan to Mauritania and all points between.

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History since 1400 4R-OL-4C

Explores the history and interaction of major world regions since about 1400, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 231 Global Writing and Intercultural Communication 4R-OL-4C

Analyzes rhetorical traditions and communication styles within and across diverse cultures as well as global uses of English. Introduces students to theories and practices for communicating and collaborating across languages and cultures.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction's humanistic usefulness in examining human values from an "extra-species, extra-terrestrial" perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 243 Music History (Before 1650): Early European Music 4R OL 4C

Surveys the early music of Europe in the Medieval, Renaissance, and early Baroque periods and explores problems of accessing musical practices distant and distinct from our own

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS 324 Brazil Since 1500 4R-OL-4C

Provides a basic understanding of Brazilian history, major political parties and issues, geography, economy, and major social and cultural phenomena. Explores the creation of a multicultural society, Brazil's place in global systems, and other issues.

GS 330 Contemporary Global Film 3R-3L-4C

Examines films outside of the Hollywood tradition with a consideration of the cultural, political, and economic influences that shape film.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 339 Contemporary Global Film 4R OL 4C

Surveys world cinema, emphasizing the importance of situating films within their historical and cultural background as well as recognizing the tensions between art and business in the film industry and how that shapes the medium.

GS 343 Musics of the World 4R OL 4C

Surveys the role of music in human cultures around the world and explores problems of accessing musical practices distant and distinct from our own, as well as thinking critically about those most familiar to us.

GS 350 International Trade and Globalization 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Prereq: SV 152 or SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Prereq: SV 151 or SV 152

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Tokyo 4R-OL-4C

Explores Tokyo from its origins to contemporary place as a “global capital” through history, geography, and culture.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 380 Japanese Popular Culture 4R-OL-4C

Examines various aspects of Japanese popular culture including society, arts, history, education, and media.

GS 384 Japanese Society 4R-OL-4C

Introduces contemporary Japan from an anthropological perspective with an emphasis on the contradictions between hyper-modernity and traditionalism.

GS 386 Hispanic Culture and Civilization (Latin America) 4R-OL-4C Prerequisite: SP213 or permission of instructor

Introduces Hispanic culture and civilization from its origins to the present. Examines Hispanic Latin American societies through cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spanish Latin America. Taught in Spanish.

GS 387 Hispanic Culture and Civilization (Spain) 4R-OL-4C Prerequisite: SP213 or permission of instructor

Introduces Hispanic culture and civilization from its origins to the present. Examines Spanish society through cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spain. Taught in Spanish.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same

as GE412.

GS 413 Nazi Germany: Fact and Fiction 4R 0L 4C

Examines the history of Nazi Germany as well as its representation in literature, film, and new media.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS 425 Cities and Technology in the Industrial Age 4R-OL-4C

Explores development of cities and the machines and systems that make them possible as human life became more and more urban and industrial from 1700 to the present. Compares urban growth and city life in different parts of the world.

GS 429 Greek and Roman Drama 4R-OL-4C

Examines drama in the classical world with special emphasis on the ways it was produced, staged, and acted. Close reading of plays by the Greek and Roman dramatists in translation.

GS 430 World Drama 4R-OL-4C

Examines drama from multiple cultures and time periods through a thematic lens.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS 470 Japanese Media 4R-OL-4C

Explores historical and contemporary media-related Japanese culture, both in visual and text communications.

GS 480 Leadership & Global Challenges 4R 0L 4C Prereq: Junior or senior standing; cross listed with EMGT536

Examines the art of leadership and its development in our increasingly globalized society by studying general theoretical approaches, with close attention to the unique challenges which globalization and cross cultural interactions impose upon leaders.

GS 485 Seminar on Japanese Society 4R-OL-4C

Provides students a firm grounding in Western intellectual engagement with Japan, particularly from an anthropological perspective. Considers how Japan has been created and framed as a site of study through close readings of relevant ethnographic literature.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps,

regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

GS CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

IDEAS AND ARTS -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R OL 4C

Introduces the methods and subject matter of philosophy through examination of some of the major problems and figures in classical and contemporary philosophy, including the nature of reality, the existence of God, the criteria of knowing, the nature of mind, and the foundations of morality.

IA 102 Critical Thinking and Introduction to Logic 4R OL 4C

Introduces students to philosophical methodology for examining the truth of claims and the quality of arguments used to defend them, including informal logic, i.e., the study of arguments in natural language, as well as formal logic, i.e., the study of inference with purely formal content, for the purpose of clarifying thinking and improving reasoning.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Communicating STEM to a Public Audience 4R-OL-4C

Examines the role of scientists and engineers as public intellectuals who can influence policy and public understanding. Emphasizes strategies for communicating technical knowledge to public audiences through

popular media.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 3R-3L-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Fundamentals of Tonal Music 4R OL 4C

Pursues the initial stages of literacy in western tonal music, from rhythm and pitch to basic functional harmonic analysis.

IA 299 Introduction to Theater Arts 4R-OL-4C

Explores the whole mechanism of the modern theater and how it works, including principles and theories of theatrical art: production, direction, acting, scenic design, costume design, lighting design, makeup, sound and multimedia, and theater architecture.

IA 301 Philosophy of Mind 4R OL 4C

Focuses on the philosophical investigation of the nature of the mind, its relationship to the brain/body, the phenomenon known as consciousness, and a host of related issues including freedom of the will and its implications for moral responsibility, the relationship between philosophy, psychology, and neuroscience, the nature of self and personal identity, the possibility of machine and animal consciousness, and the idea of mental disorder.

IA 302 Philosophy of Religion 4R OL 4C

Examines the nature and existence of God and religious experience, the meaning of religious language, and the relationship between religion, science, and philosophy through analysis of classical and contemporary texts and teachings of major figures in theology and philosophy.

IA 303 Political Philosophy 4R OL 4C

Examines the philosophical foundations of social and political organization, governance, rights, liberty, law, individualism, and justice. This course explores fundamental questions about organized society by engaging with classical and contemporary texts dealing with the state of nature, the idea of a social contract and its opposition, democracy and its ideals, virtues, and difficulties, human rights and liberties, alternatives to democracy including communism and communitarianism, and feminist and individualist theories.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 330 Documentary Film 3R-3L-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 338 Medicine in Literature 4R-OL-4C

Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 340 Ethics in Human Communication 4R-OL-4C

Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 341 Steinbeck and American Society 4R OL 4C

Studies selected writings by John Steinbeck and his contemporaries to examine their views about America as a nation, its social upheavals, morals, and paradoxes in the twentieth century. Weaves a broad context for students to debate on ideologies, ethics, values, government, and purpose of art.

IA 342 Modern Southern Fiction 4R OL 4C

Examines the major writers of the American South (both the modern and contemporary periods). Emphasizes recurrent social themes and fictional methods.

IA 343 Visual Rhetoric and Graphic Novels 4R-OL-4C

Explores the relationships between art and argument in comic books and graphic novels. Provides a vocabulary for students to discuss, analyze, and produce graphic communication, including the creation of their own mini-comic. (No drawing skills required).

IA 344 Writing in a Digital Age 4R-OL-4C

Examines the influence of digital technologies on the ways we read, produce texts, and interact. Emphasizes strategies for producing new media texts, such as podcasts, blogs, infographics, and "viral" videos.

IA 346 Music Theory II: Basic Form and Composition 4R-OL-4C Prereq: IA246 or consent of instructor

Explores intermediate topics in western tonal music and applies theoretical concepts to music composition. Forms studied and composed include simple classical and popular music genres.

IA 348 Music Performance 1R-OL-1R Prereq: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C S Prereq: SV 150 or SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C W Prereq: SV 151 or SV 152

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Prereq: SV 150 or SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C S (even years) Prereq: SV 150 or SV 151 or SV 152

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 371 Cognitive Psychology 4R OL 4C

Explores how the mind works using experimental findings and psychological models. Topics include perception, attention, memory, reasoning, decision making, and language.

IA 380 Literature and Human Rights in Latin America 4R-OL-4C

Explores testimonial narratives, which give a “voice to the voiceless,” allowing marginalized peoples to bear witness to human rights abuses. Examines testimonial narratives in terms of historical context, structure, narrative voice, and effectiveness in addressing situations of oppression and violence. Taught in English.

IA 388 Food, Culture, and the Self 4R-OL-4C

Examines food as a focus for deeper inquiry into culture, identity, national development, globalization and social change.

IA 389 Anthropology of Addiction 4R-OL-4C

Examines the concept of addiction – a frequently used yet rather imprecise term -- from a variety of perspectives to better understand this complex term and cultural concept.

IA 401 Philosophy of Science 4R OL 4C

Examines a range of philosophical questions about the methods, foundations, assumptions, and scope of science, including: How does science work? Can science reveal truths about the structure of the world? What is the scientific method and how is it different from other forms of knowledge acquisition, such as philosophy? What is a scientific explanation? What counts as evidence for a theory? What are scientific laws? These and other questions will be explored by engaging with a variety of classical and contemporary philosophical texts and arguments.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

IA 471 Computational Psychology 4R OL 4C Pre: BE 100 or CSSE 120 or ME 123 or Consent of Instructor

Explores computational principles that can be used to explain human learning and develop intelligent machines. Includes programming assignments.

IA CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or

practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

SOCIETY AND VALUES -- Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 130 Introduction to Disability Studies 4R-OL-4C

Introduces disability studies, a multi-disciplinary field that identifies, challenges, and re-conceptualizes representations of disability. Topics may include disability history and policy, activism, bioethics, and the role of technology and engineering in our perceptions of disability.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 150 Introduction to Microeconomics 4R-OL-4C F,W,S

Analyzes the market behavior of buyers and sellers. Topics include demand and supply, costs, competition, oligopoly, monopoly, economic efficiency and resource allocation, the effects of government intervention, and international trade. A student cannot take both SV 150 and SV 151, Principles of Economics, for credit.

SV 151 Principles of Economics 4R-OL-4C F, W, S

Includes both microeconomics and macroeconomics. Analyzes market behavior. Considers production and pricing decisions under alternative industrial structures. Examines the determinants of economic growth, unemployment and inflation, including fiscal and monetary policy.

SV 152 Introduction to Macroeconomics 4R-OL-4C F,W,S

Analyzes the performance of the entire economy. Topics include demand and supply, GDP, unemployment and inflation, the impact of monetary and fiscal policy, business cycles, determinants of economic growth, and international finance. A student cannot take both SV 152 and SV 151, Principles of Economics, for credit.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

A broad survey of the scientific study of mind and behavior. Topics include learning, perception, emotion, motivation, memory, childhood development, personality, social behavior, and psychological disorders.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV 244 Music History (1600 to 1900): The Common Practice Period 4R OL 4C

Surveys western classical music in the Baroque, Classical, and Romantic periods.

SV 245 Music History (After 1900): Modern and Postmodern Music 4R OL 4C

Surveys western classical music of the 20th Century.

SV 246 Music History (After 1900): The Era of Recorded Sound 4R OL 4C

Surveys the impact of audio recording revolutions of the 20th Century on jazz, film, rock, nonwestern, and classical music.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R OL 4C

Examines the ethical issues faced by professional businesspeople and engineers working in a global corporate context. Issues include the development and use of codes of professional ethics, the social responsibilities of corporations, the autonomy of professionals, whistleblowing and corporate loyalty, environmental obligations of corporations and professionals, standards of conduct in international business, and the impact of technology on our world.

SV 304 Bioethics 4R OL 4C

Examines the major moral issues in the development and practice of biomedicine and biomedical research through the analysis of philosophical and ethical theory as well as analysis of real cases of morally questionable practice in biomedicine. Topics include the autonomy and rights of patients, physicians, and researchers, informed consent and experimentation with humans and animals, the moral status of genetic and reproductive controls and interventions, the extension and termination of life, and the allocation of scarce medical resources.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20 -Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 340 American Drama 4R-OL-4C

Surveys American drama from the colonial period to the present.

SV 341 African-American Drama 4R-OL-4C

Surveys African-American drama from the early 19th century to the present.

SV 342 Modern European Drama 4R-OL-4C

Surveys modern European drama from about 1870 to the present.

SV 345 Presidential Election Rhetoric 4R-OL-4C

Increases students' awareness and understanding of the U.S. Presidential election process, candidates, campaign issues, campaign advertising, debates, and the role of the news media. Focuses on analyzing and producing rhetoric associated with presidential campaigns.

SV 351 Managerial Economics 4R-OL-4C Prereq: SV 150 or SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. Students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Prereq: SV 151 or SV 152

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Prereq: SV 150 or SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Prereq: SV 150 or SV 151 or SV 152

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Prereq: SV 150 or SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 371 Social Psychology 4R OL 4C

Explores how people's behavior, feelings, and thoughts are influenced by their social environments. Topics include attitude formation, prejudice, relationships, group behavior, conformity, altruism, and aggression.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and evolution, the fossil record, and genetics; compares human behavior with other primates; and explores the extent and causes of human physical diversity.

SV 389 Anthropology of Sports 4R-OL-4C

Introduces the study of sport through a critical anthropological lens. Sport is used to contextualize gender, health, technology, ethnic difference, nationalism, sexuality, and socioeconomic class.

SV 402 Human Nature 4R OL 4C

Examines what it means to be human by examining major philosophical texts in the Western tradition in conjunction with recent developments in psychology and cognitive science. The central issues include happiness and the good life, morality, justice, and the structure of human social institutions.

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C F (odd years) Prereq: SV 150 or SV 151 or SV 152

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

SV CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

COMMUNICATION

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis of texts and images, research methods, and the conventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Prereq: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

SPECIAL TOPICS AND DIRECTED STUDY

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX456 Seminar for HSS Senior Project 2R-OL-2C F Prereq: Economics or International Studies major and Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX457 Directed Study for HSS Senior Project 2R-OL-2C Arranged Prereq: XX456 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double majors.

MODERN LANGUAGES

(NOTE: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Prereq: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Prereq: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Prereq: GE 213

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Prereq: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C

Summer Prereq: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Prereq: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-0L-4C S

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-0L-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

GS CPT / IA CPT / SV CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

HSS MAJORS

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning OutComes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 - A. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 - B. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 - C. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 - A. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 - B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 - A. Assemble and evaluate resources for research in international studies.
 - B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute

Curriculum Committee.

I. International Studies Core (24 cred.)

IA233 World Literature
GS163 International Relations
GS285 Humans and Culture
GS291 World Geography
SV151 Principles of Economics
GS223 World History

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

- a. International Political Economy: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose at least three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General List

IA353 History of Economic Thought
GS322 Industrial Revolution in a Global Context
GS350 International Trade and Globalization
GS351 International Finance
GS352 Economic Growth and Development
GS361 Politics of the Global Economy
SV328 Comparative Business History
SV354 Environmental Economics

Regional List

GS128 Introduction to East Asia
GS161 Comparative Politics
GS222 Modern Latin American
GS366 European Union
GS363 European Politics and Government
GS399 Geography of the Middle East
GS492 Geography of Africa

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

- a. Comparative Cultures: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322 Industrial Revolution in Global Context
GS333 Travel in World Literature
GS334 Global Novel in the 20th Century
GS432 Literature of the Global Economy
GS462 Postcolonial Literature
SV191 Cultural Geography
SV201 Religion and Ecology
SV226 The West in the East
SV382 Anthropology of Religion

Regional list (including but not limited to the following courses)

IA311 Topics in German Culture I

- GS128 Introduction to East Asia
- GS207 Asian Religions and Philosophy
- GS222 Modern Latin America
- GS313 Contemporary Spain
- GS327 Modern China
- GS335 Arabic Literature
- GS379 Japanese Culture
- GS391 Contemporary Europe
- GS442 Art History: Renaissance to Modern
- GS492 Geography of Africa

- 1. Individualized Major: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS MINORS

MINOR IN ANTHROPOLOGY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

- 1. Five Courses in Anthropology.
- 2. The following three courses are required:
 - o GS 285 Humans & Culture
 - o SV 385 Archaeology & Prehistory
 - o SV 386 Human Evolution
- A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- Substitutions may be made with the approval of the Minor Advisor

Courses

- o GS 384 Japanese Society
- o SV 382 Anthropology of Religion
- o XX 399 Special Topics
- o XX 499 Directed Study

MINOR IN ART

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

- 1. Five Courses in Art:
 - a. The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242 Visual Arts in Civilization
- 2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- 3. Substitutions may be made with the approval of the Minor Advisor

Courses

- o GS442 Art History: Renaissance to Modern
- o IA142 Drawing
- o IA148 Beginning Photography

- IA244 Design and Color
- SV242 Visual Arts in Civilization

MINOR IN EAST ASIAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS128 Introduction to East Asian History
 - GS207 Asian Religions and Philosophy
 - GS324 Gender and Work in China
 - GS327 Modern China
 - GS384 Japanese Society
 - SV226 The West in the East
 - SV326 Overseas Chinese
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN ECONOMICS

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Principles of Economics (SV 151);
 - b. Intermediate Microeconomics (IA 350) and Intermediate Macroeconomics (IA 351);
 - c. Two additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- GS350 International Trade and Globalization
- GS351 International Finance
- GS352 Economic Growth and Development
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- IA352 Game Theory
- IA353 History of Economic Thought
- IA450 Mathematical Economics
- IA453 The Entrepreneur
- SV151 Principles of Economics
- SV351 Managerial Economics
- SV352 Money and Banking
- SV353 Industrial Organization
- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX499 Directed Study

MINOR IN EUROPEAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - o GS313 Contemporary Spain
 - o GS337 Shakespeare's Europe
 - o GS363 European Politics and Government
 - o GS366 The European Union
 - o GS431 Literary London
 - o GS469 Contemporary British Fiction and Film
 - o GS491 Geography of Europe
 - o IA311 Topics in German Culture I
 - o IA337 European Romanticism
 - o SV222 Western Civilization to 1500
 - o SV223 Western Civilization from 1500 to the Present
 - o SV291 Medieval Europe
 - o SV413 Contemporary Germany
 - o XX399 Special Topics
 - o XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN GEOGRAPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- o GS191 Geography of Middle East
- o GS222 Modern Latin America
- o GS291 World Geography
- o GS327 Modern China
- o GS391 Contemporary Europe
- o GS491 Geography of Europe
- o GS492 Geography of Africa
- o SV191 Cultural Geography
- o SV291 Medieval Europe
- o XX399 Special Topics
- o XX499 Directed Study

MINOR IN HISTORY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- o GS221 Colonial Latin America
- o GS223 World History
- o GS222 Modern Latin America
- o GS325 Cities and Technology
- o GS413 Nazi Germany: Fact and Fiction
- o GS422 Industrial Revolution in Global Context

- SV222 Western Civilization to 1500
- SV223 Western Civilization since 1500
- SV322 Disasters and Modern Society since 1700
- SV329 Cities in Latin American History
- XX399 Special Topics
- XX499 Directed Readings

MINOR IN LANGUAGE AND LITERATURE

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and RH 330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS237 Science Fiction
- GS334 Travel in World Literature
- GS335 The Global Novel in the Twentieth Century
- GS336 Literature of War
- GS337 Shakespeare's Europe
- GS338 Contemporary Arabic Literature in Translation
- GS339 Contemporary Global Film
- GS412 Topics in German Culture II
- GS431 Literary London
- GS432 Literature and Film of the Global Economy
- GS462 Postcolonial Literature
- GS469 Contemporary British Fiction and Film
- IA230 Fundamentals of Public Speaking
- IA231 Introduction to Poetry
- IA232 African American Music in American Literature
- IA233 World Literature
- IA234 Major American Writers
- IA235 Major British Writers
- IA237 Introduction to Drama
- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature
- IA337 European Romanticism
- IA338 Medicine in Literature
- IA339 Rebellion in American Literature
- IA341 Steinbeck and American Society
- IA342 Modern Southern Fiction
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Gender, Work & Popular Culture
- SV334 Utopian Thought and Literature
- SV336 Contemporary American Fiction
- SV337 20th century American Novel
- SV339 Literature and the Environment

- SV234 The American Dream
- XX399 Special Topics
- XX499 Directed Study

MINOR IN LATIN AMERICAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS221 Colonial Latin America
 - GS222 Modern Latin America
 - GS323 The Andean Countries of South America
 - GS313 Contemporary Spain
 - IA332 Don Quixote
 - SV329 Cities in Latin American History
 - SV338 Latin American Fiction: The Boom and Beyond
 - XX399 Special Topics
 - XX499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN MODERN LANGUAGES (GERMAN, JAPANESE, AND SPANISH)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture IV/V/VI
SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation
Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413
Japanese Language and Culture X/XI/XII

XX 399 Special Topics
XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.
Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

MINOR IN MUSIC

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. A minimum of five courses (20 credits) must be earned to obtain the minor. At least 16 of these credits (four courses) must be in HSS courses. The remaining four credits may be one of the approved course from outside the HSS Department listed below.
2. Both courses in music theory and at least two in music history are required.
3. A minimum of 40 hours (10 courses) of HSS credit are required to complete the minor except when an approved technical course is applied to the minor. Then the requirement is 36 hours of HSS and four hours of approved technical credit. The distribution of courses is as follows:

A. Two courses in music theory:

IA246 Music Theory I: Fundamentals of Tonal Music.

IA346 Music Theory II: Basic Form and Composition. *Pre requisite: IA246.*

Students who have taken music theory before attending Rose Hulman may choose to take a Theory I placement test in order to be granted admittance to Music Theory II. Students who successfully pursue this option must then substitute for Music Theory I another music related course, as approved by the Music Advisor.

B. Two courses in music history:

GS243 Music History (Before 1600): Medieval and Renaissance Music

SV244 Music History (1600 to 1900): The Common Practice Period

SV245 Music History (After 1900): Modern and Postmodern Music

SV246 Music History (After 1900): The Era of Recorded Sound

Other music-related courses offered within the HSS Department may be used to satisfy up to two of these four required courses.

C. To fulfill the fifth course requirement for the Area Minor in Music, the candidate may choose **ONE** of the following options:

- 1) A music related course from outside the HSS Department, approved by the Minor Advisor, such as:

ECE481 Electronic Music Synthesis

PH404 Acoustics

PH460 Directed Study in Physics

- 2) A music related course offered within the HSS Department, approved by the Minor Advisor, such as:

GS343 Musics of the World

IA499 Directed Study in Music *Pre requisite: consent of the Minor Advisor*

- 3) IA348 Music Performance. *Pre requisite: consent of the Minor Advisor and ensemble directors.* Four (4) credits of satisfactory participation in one or more of the formal Performing Groups (Concert Band, Jazz Ensemble, String Ensemble, and Chorus) are required. One academic term of satisfactory participation earns one credit. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for "satisfactory participation" will be provided to the candidate by the ensemble directors.

Any course taken to satisfy the four required Music Theory and Music History courses cannot also be used to satisfy the fifth course requirement.

MINOR IN PHILOSOPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy has the following requirements:

1. Five courses in Philosophy, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Philosophy Courses:

- IA101 – Introduction to Philosophy
- IA102 – Critical Thinking & Introduction to Logic
- IA401 – Philosophy of Science
- IA302 – Philosophy of Religion
- IA301 – Philosophy of Mind
- IA303 – Political Philosophy
- SV402– Human Nature
- SV303 – Business & Engineering Ethics
- SV304 – Bioethics
- XX399 – Special Topics
- XX499 – Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS161 Comparative Politics
- GS163 International Relations
- GS361 Politics of the Global Economy
- GS366 The European Union
- SV166 American Politics and Government
- SV369 British Politics and Government
- SV463 Seminar on America's Future
- XX399 Special Topics
- XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Principles of Psychology (SV 171).
2. Four other psychology courses.
3. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
4. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
5. Substitutions may be made with the approval of the Minor Adviser.

Courses:

- SV171 Principles of Psychology

IA371 Cognitive Psychology

- IA471 Computational Psychology
- SV372 Social Psychology
- IA301 Philosophy of Mind

Minor in Theater and Drama

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

Requirements:

1. Five courses (20 credits) in Theater and Drama.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the minor advisor.

Courses:

- IA 299 Introduction to Theater Arts
- IA 237 Introduction to Drama
- IA 240 Introduction to Shakespeare
- SV 340 American Drama
- SV 341 African American Drama
- SV 342 Modern European Drama
- GS 337 Shakespeare's Europe
- GS 429 Greek and Roman Drama
- GS 430 World Drama

GERMAN TECHNICAL TRANSLATOR’S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute’s degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator’s Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for

details.

- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60



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Programs of Study

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Army ROTC (Military)

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student’s choice of commissioning program and Army requirements.

CURRICULUM

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College,

- Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- International Computer Science
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Army ROTC (Military)
- Pre-Professional Programs

University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

ADVANCED COURSE

Freshman Year

		Credit
MS 101	Leadership and Personal Development	1
MS 102	Introduction to Tactical Leadership	1
MS 103	Basic Tactical Leadership	1
		3

Sophomore Year

		Credit
MS 201	Innovative Team Leadership	2
MS 202	Foundations of Tactical Leadership	2
MS 203	Foundations of Tactical Leadership II	2
		6

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Summer

MS 206	ROTC Basic Camp	0
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Junior Year

		Credit
MS 301	Adaptive Team Leadership	4
MS 302	Leadership Under Fire	4
MS 303	Leadership Under Fire II	4
		12

Senior Year

		Credit
MS 401	Developing Adaptive Leaders	4
MS 402	Leadership in a Complex World	4
MS 403	Leadership in a Complex World II	4
		12

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training..



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Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose-Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

International Computer Science

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Air Force ROTC (Military)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS)
(Second Major Only)

International Studies Major (IS) (Second Major Only)

Army ROTC (Military)

Pre-Professional Programs



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Air Force ROTC (Military)

LT Col Morgan III, CAPT Jeffers

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Prereq: None

This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Prereq: AS 101 or instructor permission

This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Prereq: AS 102 or instructor permission

This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Prereq: Enrollment in AS 101, AS 102, or AS 103

Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Prereq: AS 103 or instructor permission

This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Prereq: AS 201 or instructor permission

This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Prereq: AS 202 or instructor permission

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

This course is a continuation of the winter quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Prereq: Enrollment in AS 201, AS 202, or AS 203

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Prereq: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Prereq: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Prereq: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Prereq: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Prereq: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Prereq: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Prereq: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Prereq: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Army ROTC (Military)

LTC Eric Walthall and MSG Zoleske

FRESHMAN YEAR Basic Course

MS 101: Leadership and Personal Development 1R-3L-1C F Prereq: None

MS 101 introduces cadets to the personal challenges and competencies that are critical for effective leadership. Cadets learn how the personal development of life skills such as critical thinking, goal setting, time management, physical fitness, and stress management relate to leadership, officership, and the Army profession. The focus is on developing basic knowledge and comprehension of Army leadership dimensions while gaining a big picture understanding of the ROTC program, its purpose in the Army, and its advantages for the student.

MS 102: Introduction to Tactical Leadership 1R-3L-1C W Prereq: MS 101 or Instructor Permission

MS 102 overviews leadership fundamentals such as setting direction, problem-solving, listening, presenting briefs, providing feedback, and using effective writing skills. Cadets explore dimensions of leadership values, attributes, skills, and actions in the context of practical, hands-on, and interactive exercises. Continued emphasis is placed on recruitment and retention of cadets. Cadre role models and the building of stronger relationships among the cadets through common experience and practical interaction are critical aspects of the MS 102 experience.

MS 103: Basic Tactical leadership 1R-3L-1C S Prereq: MS 101 and 102 or Instructor Permission

MS 103 continues the exploration of leadership fundamentals and examines the leadership process as affected by individual differences and styles, group dynamics, and personality behavior of leaders. Students will experience an introduction of fundamental leadership concepts, and examine factors that influence leader and group effectiveness. Students will fully explore the basic soldier skills and squad level tactical operations. Students participate in briefings and hands-on practical exercises. Attention is devoted to development of leadership potential through practical exercises both in and out of the classroom.

SOPHOMORE YEAR Basic Course

MS 201: Innovative Team Leadership 2R-3L-2C F Prereq: MS 101, 102, and 103 or Instructor Permission

MS 201 explores the dimensions of creative and innovative tactical leadership strategies and styles by examining team dynamics and two historical leadership theories that form the basis of the Army leadership framework. Cadets practice aspects of personal motivation and team building in the context of planning, executing, and assessing team exercises and participating in leadership labs. Focus is on continued development of the knowledge of leadership values and attributes through an understanding of Army rank, structure, and duties and basic aspects of land navigation and squad tactics. Case studies provide tangible context for learning the Soldier's Creed and Warrior Ethos as they apply in the contemporary operating environment (COE).

MS 202: Foundations of Tactical Leadership 2R-3L-2C W Prereq: MS 201 or Instructor Permission

MS202 examines the challenges of leading tactical teams in the COE. The course highlights dimensions of terrain analysis, patrolling, and operation orders. Further study of the theoretical basis of the Army leadership framework explores the dynamics of adaptive leadership in the context of military operations. Cadets develop greater self awareness as they assess their own leadership styles and practice communication and team building skills. COE case studies give insight into the importance and practice of teamwork and tactics in real world

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

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Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

scenarios.

MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Prereq: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Leaders' Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Leaders' Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

JUNIOR YEAR Advanced Course

MS 301: Adaptive Team Leadership 3R-3L-4C F Prereq: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 challenges cadets to study, practice, and evaluate adaptive leadership skills as they are presented with challenging scenarios related to squad tactical operations. Cadets receive systematic and specific feedback on their leadership attributes and actions. Based on such feedback, as well as their own self-evaluations, cadets continue to develop their leadership and critical thinking abilities. The focus is developing cadets' tactical leadership abilities to enable them to succeed at ROTC's summer Leadership Development and Assessment Course (LDAC).

MS 302: Leadership Under Fire 3R-3L-4C W Prereq: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when under fire are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Leader Development and Assessment Course (LDAC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Prereq: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for LDAC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

**Overview of LDAC: Leader Development and Assessment Course
Summer Term Only**

LDAC/Warrior Forge is the crucible of the Army ROTC Program. As such, Cadet Command must provide the best professional training and evaluation possible for all cadets. The primary focus at LDAC is to evaluate each cadet's officer potential in a collective environment. The secondary purpose of LDAC is to validate specific skills taught on campus and to impart selective individual and collective common skills. LDAC represents the only opportunity for this command to assemble cadets from disparate schools into an environment with common operational conditions.

SENIOR YEAR- Advanced Course

MS 401: Developing Adaptive Leaders 3R-3L-4C F Prereq: MS 303

MS 401 develops cadet proficiency in planning, executing, and assessing complex operations, functioning as a member of a staff, and providing performance feedback to subordinates. Cadets assess risk, make ethical decisions, and lead fellow ROTC cadets. Lessons on military justice and personnel processes prepare cadets to make the transition to Army officers. Cadets analyze, evaluate, and instruct cadets at lower levels. Both their

classroom and battalion leadership experiences are designed to prepare cadets for their first unit of assignment. They identify responsibilities of key staff, coordinate staff roles, and use situational opportunities to teach, train, and develop subordinates.

MS 402: Leadership in a Complex World 3R-3L-4C W Prereq: MS 401

MS 402 explores the dynamics of leading in the complex situations of current military operations in the COE. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. They also explore aspects of interacting with nongovernmental organizations, civilians on the battlefield, and host nation support. The course places significant emphasis on preparing cadets for their first unit of assignment. It uses case studies, scenarios, and What Now, Lieutenant? exercises to prepare cadets to face the complex ethical and practical demands of leading as commissioned officers in the United States Army.

MS 403: Leadership in a Complex World II 3R-3L-4C S Prereq: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biology & Biomedical Engineering

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Biology

BIO 101 Essential Biology 4R-OL-4C F,W,S Prereq: None

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed BIO110, BIO120 or BIO130 cannot receive credit for taking BIO101.

BIO 102 Nutrition 4R-OL-4C W Prereq: None

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for BIO or BE majors and not as an BIO elective.

BIO 110 Cell Structure and Function 3R-3L-4C F,S Prereq: None

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

BIO 120 Comparative Anatomy & Physiology 3R-3L-4C W Prereq: None

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

BIO 130 Evolution and Diversity 3R-3L-4C S Prereq: None

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

BIO 191 Special Topics in Biology XR-OL-XC Arranged Prereq: Consent of instructor

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed BIO course.

BIO 205 Cellular Physiology 4R-OL-4C F Prereq: BIO 110

The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for BIO205 cannot earn credit for BIO210 or BIO230 without departmental consent.

BIO 210 Mendelian and Molecular Genetics 3R-3L-4C F Prereq: BIO 110 or instructor consent

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

BIO 220 Prokaryotic Cell and Molecular Biology 3R-3L-4C W Prereq: BIO 110 or instructor consent

Discusses the essential properties of eubacteria and archea. Bacterial nutrition, growth, genetics and structural

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Army ROTC (Military)

Biology & Biomedical Engineering

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College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

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Multi-Disciplinary Studies

Optical Engineering

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and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

BIO 230 Eukaryotic Cell and Molecular Biology 3R-3L-4C S Prereq: BIO 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

BIO 264 Introduction to Environmental Science 4R-0L-4C W Prereq: CHEM 113 and CHEM 113L

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

BIO 310 Plant Structure & Function 3R-3L-4C S Prereq: BIO 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

BIO 320 Ecology 3R-3L-4C F Prereq: BIO 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

BIO 330 Evolutionary Biology 4R-0L-4C W Prereq: BIO 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

BIO 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Prereq: BIO 120, and Jr/Sr standing or consent of instructor

Designed to introduce biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

BIO 399 Practice of Science 4R-0L-4C Prereq: RH 330 and MA 223, or consent of instructor

This course focuses on skills required for implementing scientific research, including reading the primary literature, experimental design, scientific writing, oral presentations, research proposal writing, poster presentations, and investigation of research programs (through seminars or individual meetings). Each student chooses a project and research mentor by the end of the course.

BIO 410 Infection and Immunity 4R-0L-4C Arranged Prereq: BIO 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

BIO 411 Genetic Engineering 4R-0L-4C Arranged Prereq: BIO 205 or BIO 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

BIO 421 Applied Microbiology 4R-0L-4C Arranged Prereq: BIO 110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

BIO 431 Genomics and Proteomics 4R-0L-4C S Prereq: BIO 205 or BIO 210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

BIO 441 Virology 3R-3L-4C Prereq: BIO 110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

BIO 451 Cancer Biology 4R-0L-4C Prereq: BIO 205 or BIO 210 or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

BIO 461 Evolutionary Medicine 4R-0L-4C Arranged Prereq: BIO 130, and BIO 205 or BIO 210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

BIO 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged Prereq: BIO 205 or BIO 210 or consent of instructor

Strategies and methods used to identify and understand the genetic and molecular bases of inherited human disease are addressed. Topics include, human population genetics, pedigrees, genetic and physical mapping of human genes, linkage analysis, and diagnostic testing. Primary literature is routinely utilized.

BIO 491 Special Topics in Biology XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed BIO course.

BIO 492 Directed Study in Biology XR-XL-XC Arranged Prereq: Consent of instructor

Covers biology material of mutual interest to the student and instructor which cannot be experienced in any other listed BIO course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the BBE department is required to use this course to fulfill BIO elective credit requirements.

BIO 496 Senior Thesis Research I 0R-6L-2C F,W,S Prereq: BIO 399 and consent of instructor

Initiation of senior thesis under the direction of an BBE faculty mentor. Major tasks include creation and submission of a research proposal and piloting procedures. Additional requirements for adequate progress determined by each faculty mentor.

BIO 497 Senior Thesis Research II 0R-12L-4C F,W,S Prereq: BIO 399 and consent of instructor

Continuation of research under the direction of an BBE faculty mentor. Major tasks include data acquisition and methodological refinement. Additional requirements for adequate progress determined by each faculty mentor.

BIO 498 Senior Thesis Research III 0R-12L-4C F,W,S Prereq: BIO 399 and consent of instructor

Continuation of research under the direction of an BBE faculty mentor. Major tasks include data acquisition and preliminary analysis. Additional requirements for adequate progress determined by each faculty mentor.

BIO 499 Senior Thesis Research IV 0R-6L-2C W Prereq: BIO 399 and consent of instructor

Completion of senior thesis under the direction of an BBE faculty mentor. Major tasks include final analysis, public presentation of results, and submission of the written thesis. Additional requirements for adequate progress determined by each faculty mentor.

BIO CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4C S Prereq: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE 201 Biomedical Measurements 3R-3L-4C W, S Prereq: BE 100, ES 203

Discussion of measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors

(temperature, force, pressure, velocity, etc), and basics of microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I 3R-3L-4C W Prereq: BIO 120, BIO 205

An analysis of neural, muscular, and endocrine physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Prereq: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of cradle to cradle design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II 3R-3L-4C S Prereq: BE310

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3C W Prereq: ES 201, EM 204, and BE 201, or consent of instructor Co: BE 351 or BE352, and BE 361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Instrumentation and Signal Processing 3R-3L-4C F Prereq: BE 201, ES 203

This course introduces the fundamental of biomedical signal processing strategies. Topics include data acquisition, A/D and D/A conversion, digital filter design, time-frequency analysis, and I/O interfaces. Multichannel data processing and high dimensional data analysis techniques are also covered. Lectures will be accompanied by data analysis assignments and projects using MATLAB, LabVIEW, and microcontrollers.

BE 350 Biocontrol Systems 4R-0L-4C Prereq: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE 351 Biomedical Engineering Lab 1R-3L-2C Coreq: BE 331 and BE 361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE 352 Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE 331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 353 Biomaterials Lab 0R-3L-1C Prereq: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE 361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 385 Quality Methods 4R-0L-4C S Prereq: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran,

and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as MA 385

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Prereq: BE 201, Coreq: EM 204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 400 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Prereq: BE 390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Prereq: BE 410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Prereq: BE 420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 482 Bioengineering Statistics 4R-0L-4C Prereq: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Prereq: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F,W,S Prereq: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing 3R-3L-4C W Prereq: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Analysis of Physiological Systems I 3R-3L-4C W Prereq: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Analysis of Physiological Systems II 3R-3L-4C S Prereq: Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 520 Introduction to Brain Machine Interfaces 3R-3L-4C S Prereq: BE340 or ECE480

This course is an introduction to the basics of motor cortical functions related to voluntary and imagery movements, evoked response potentials, invasive vs. noninvasive electrode design considerations, quantitative EEG analysis techniques used in clinical settings, and the applications of brain-machine interfaces/brain-computer interfaces in the restoration of mobility, communication and motor function.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Prereq: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Prereq: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3 R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 212 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 535.

BE 539 Multiscale Biomechanics 3R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and BE340, or BE340 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as ECE584.

BE 543 Neuroprosthetics 3R-3L-4C Prereq: BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Prereq: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Prereq: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Prereq: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Prereq: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 565 Experimental Methods in Tissue-Biomaterial Interactions 3R-3L-4C S Prereq: BE 361, or consent of instructor

This course focuses on teaching students experimental methods used for investigations of tissue-biomaterial interactions. Topics include bioethics issues associated with experiments on cells, tissues, animals, and people; biosafety issues associated with cells/tissues from animals and humans; the design, critique, and statistical analysis of experiments. Students conduct hands-on investigations of cell-biomaterial interactions which require the use of common laboratory equipment, aseptic technique, mammalian cell culture, and current molecular methods to investigate cell viability, structure, and function.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Prereq: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 Selected Topics F,W,S

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.

BE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or

practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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Chemical Engineering

Professors Artigue, Chenette, Coronell, Gupta, Hariri, D. Henthorn, K. Henthorn, McClellan, Nolte, Sauer, and Serbezov.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Prereq: None
An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 1R-0L-0C F Prereq: sophomore standing in Chemical Engineering
Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F Prereq: CHEM 113 or concurrent registration in CHEM 112, MA 113 or concurrent registration, and PH 111 or concurrent registration
An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Prereq: CHE 201
The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 300 Career Preparation II 0L-0C F Prereq: Junior standing in Chemical Engineering
Career choices; preparation of resume; preparation for summer positions; preparation for graduate programs. 2-5 contact hours per quarter.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Prereq: CHE 201
Physical properties of fluids, fluid statics, laminar and turbulent flow, boundary layer concept, flow past objects and flow through porous media. Design of pipe networks and pumps. High speed ideal gas flow. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Prereq: CHE 202, MA 211 Coreq: CHE 110
First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F,W Prereq: CHE 303, MA 212
Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Prereq: CHE 110, MA 211, MA 212 or concurrent enrollment

The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Prereq: CHEM 115 or consent of instructor

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Prereq: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304

Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Prereq: CHE 320, CHE 304

Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Prereq: CHEM 360 and CHE 304

The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Prereq: Senior Standing in Chemical Engineering

Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Prereq: CHE 321, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Prereq: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Prereq: CHE 321

Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Prereq: CHE 416, CHE 404

Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Prereq: CHE 417 or consent of instructor

Completion of an open-ended design project that will include written and oral communication of intermediate results and a final written report.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W Prereq: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F Prereq: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 450 Air Pollution 4R-0L-4C F or W Prereq: Junior or Senior standing

An introduction to air pollution and its control with special emphasis on the engineering aspects. Discussions of meteorology, health effects, sources and types of pollution, industrial control technology. Student projects. Cross-listed with CE561.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Prereq: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Prereq: CHE 303 or CHEM361 or ME201 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S Prereq: CHE303

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F,W,S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F,W,S Prereq: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

CHE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

CHE 502 Transport Phenomena I 4R-0L-4C Prereq: CHE 321 or consent of instructor

Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 503 Transport Phenomena II 4R-0L-4C

Energy Transport: multidimensional systems; macroscopic balances for nonisothermal systems. Mass Transport: fundamentals of ordinary diffusion, multicomponent diffusion, pressure and thermal diffusion, coupled heat and mass transfer, boundary layer analysis, turbulent transport, mass transfer coefficients, macroscopic balances.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W (proposed) Pre: CHE 321 or consent of instructor

Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 511, ME 519, and ECE 519.

CHE 521 Advanced Chemical Engineering Computation 4R-0L-4C

The application of advanced mathematics to chemical engineering problems. The topics include: the formulation of the partial differential equations of kinetics and heat, mass and momentum transfer problems; series solution techniques; transform solution techniques; vector formulation; numerical methods for systems of differential equations; optimization, including linear programming, combinatorial optimization, and stochastic optimization techniques.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: AB110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: AB110, CHE 321 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Chemistry and Biochemistry

Professors Allison, Brandt, R. DeVasher, Erwin, Hoffman, Morris, Mottel, Mueller, Tilstra, Weatherman and Wilson.

CHEM 111 General Chemistry I 3R-3L-3C F,W,S Prereq: None; Coreq: CHEM111L
Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 111L General Chemistry I Laboratory 0R-3L-1C F,W,S Prereq: None; Coreq: CHEM 111
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM111 recitation.

CHEM 112 Chemistry Honors 4R-3L-5C F Prereq: Advanced placement
An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-3C W,S Prereq: CHEM 111 and CHEM 111L; Coreq: CHEM 113L
Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 113L General Chemistry II Laboratory 0R-3L-1C W,S Prereq: CHEM 111 and CHEM 111L; Coreq: CHEM 113
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 115 General Chemistry III 3R-3L-3C W,S Prereq: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 115L
Topics in this course include acid-base reactions, electrochemistry, and coordination chemistry.

CHEM 115L General Chemistry III Laboratory 0R-3L-1C W,S Prereq: CHEM 113 and CHEM 113L or CHEM 112; Coreq: CHEM 115
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 200 Career Preparation 1R-0L-1C W
This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with MA200, and SV200.

CHEM 225 Analytical Chemistry 3R-3L-3C F, S Prereq: CHEM 115 and CHEM 115L; Coreq: CHEM 225L
This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 225L Analytical Chemistry Laboratory 0R-3L-1C F, S Prereq: CHEM 115 and CHEM 115L; Coreq: CHEM 225

This course represents the laboratory component of analytical chemistry. Practicums are part of the grade along with reports.

CHEM 251 Organic Chemistry I 3R-0L-3C F Pre: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 251L

An introduction to the classification of organic compounds, their structural features, including stereochemistry, and concepts related to reaction mechanisms and synthetic methods.

CHEM 251L Organic Chemistry I Laboratory 0R-3L-1C F Prereq: CHEM 113 and CHEM 113L, or CHEM 112; Coreq: CHEM 251

Organic Laboratory techniques are developed along with appropriate spectroscopic methods. Assessment is in part via practicums. Computational chemistry methods and green chemistry approaches are also introduced.

CHEM 252 Organic Chemistry II 3R-0L-3C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252L

Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis, and an introduction to the methods used to determine structure, including IR and NMR spectroscopy and mass spectrometry.

CHEM 252L Organic Chemistry II Laboratory 0R-3L-1C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252

A continuation of CHEM251L where additional, more complicated synthetic techniques and methods along with additional spectroscopic techniques are introduced. Assessment is in part via practicums.

CHEM 253 Organic Chemistry III 3R-0L-3C S Prereq: CHEM 252 and CHEM 252L; Coreq: CHEM 253L

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 253L Organic Chemistry III Laboratory 0R-4L-1C S Prereq: CHEM 252 and CHEM 252L; Coreq: CHEM 253

Project based laboratory where techniques and skills developed in the previous organic laboratories are applied to more open-ended problems.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Prereq: CHEM 113 and CHEM 113L

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with BIO264.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Prereq: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Prereq: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research performed under the direction of a faculty member selected by mutual agreement. This course is designed for research performed before taking CHEM291. Students may register for 1 to 2 credit hours per quarter.

CHEM 291 Introduction to Chemical Research 2R-4L-3C W Prereq: CHEM 113/113L, or 112

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members and be required to attend all seminars during the quarter.

CHEM 304 Glassblowing 1R-3L-1C S Prereq: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Prereq: CHEM 225 and CHEM 225L

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Prereq: CHEM 225 and CHEM 225L

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Prereq: CHEM 252

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Prereq: CHEM 330 and BIO 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C W, S Prereq: CHE 303, CHE 304, and CHEM 115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Prereq: CHEM 115, CHEM 115L, MA212 and MA 381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Prereq: CHEM 111, CHEM 111L, MA 212, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 371 Environmental Analytical Chemistry 3R-4L-4C F Prereq: CHEM 251 and CHEM 251L (or concurrent enrollment), and CHEM 225 and CHEM 225L and CHEM 264

This course is a laboratory-driven course where processes involved in performing environmental analytical chemistry are addressed. The focus of this course is on the chemical principles, analytical theory, instrumentation, and methods employed to quantitatively and qualitatively analyze pollutants in soil, water, biological tissues, and the atmosphere. Several techniques will be included in the course: sampling (obtaining a representative sample of complex system); sample preparation (extraction, clean-up, pre-concentration, derivitization, digestion, etc.); data acquisition (The laboratory will include use of EPA/ASTM methods/protocols, method development, etc.); and data handling and analysis (statistics, signals, noise, etc.).

CHEM 391 Research Proposal 1R-0L-1C F,W,S Prereq: CHEM 291, RH 330; Coreq: CHEM 490

Students will take online lessons related to the generation and communication of research ideas culminating in the production of a research proposal. The research proposal will be written under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 395 Chemistry Seminar 0R-0L-0C F Prereq: None

Students will be required to attend and/or present research seminars, the number to be determined by the department. The students will register for the course in the fall of the third year and if all the requirements are met, the students will receive a grade of Satisfactory. Failure to meet the requirements during the fall quarter will result in No Grade and the student must complete the requirements by the end of the third year. If the requirements are not completed by the end of the third year, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 400 Chemical Communication I 1R-0L-1C W Prereq: CHEM 291

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. The emphasis of this course is to provide instruction in written communication. The fundamental skills useful for composition of professional chemistry

communications is introduced culminating in a research prospectus. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 401 Chemical Communication II 1R-0L-1C F Prereq: CHEM 400 and CHEM 490

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. Students will learn methods associated with constructing results and analysis sections of formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 402 Chemical Communication III 1R-0L-1C W Prereq: CHEM 401

The emphasis of this course is to provide instruction in oral communication. Students will be taught fundamental skills useful for public presentation of research and its results. Students will also be required to attend the chemistry department's seminar series.

CHEM 403 Chemical Communication IV 1R-0L-1C S Prereq: CHEM 402

Students will publish a thesis and deliver a professional seminar on their undergraduate research.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 433 Biochemistry Laboratory 0R-3L-1C S Prereq: CHEM 330

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Prereq: CHEM252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Prereq: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 451 Organic Structure Determination 2R-8L-4C S Prereq: CHEM 253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Prereq: CHEM 251 or CE 564 or consent of instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F,W,S Prereq: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.

Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: Permission of instructor

Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Prereq: CHEM 291

Research performed under the direction of a faculty member selected by mutual agreement. Students may register for 1 to 3 credit hours per quarter.

CHEM 491 Research Thesis 1R-0L-1C F,W,S Prereq: CHEM 490

Students will publish a thesis on their undergraduate research. The thesis will be written under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 495 Chemistry Seminar 0R-0L-0C F Prereq: None

Students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 496 Chemistry Seminar 0R-0L-0C W Prereq: None

Students will be required to attend research seminars. If the requirement is not completed by the end of the quarter, a grade of Unsatisfactory is assigned and must be rectified to meet graduation requirements.

CHEM 497 Research Presentation 1R-0L-1C F W S Prereq: CHEM 490

Students will deliver a professional seminar on their undergraduate research. A student must have at least three credit hours of CHEM490. The seminar will be prepared under the direction of a faculty member of record for the student's CHEM490 or by other faculty member selected by mutual agreement.

CHEM 530 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules. Students enrolled in CHEM 530 must complete a project not covered in CHEM 430. A student may not receive credit for both CHEM 430 and CHEM 530.

CHEM 531 Biochemical Instrumentation 3R-4L-4C Prereq: BIO 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 532 Biochemical Pharmacology 4R-0L-4C Prereq: CHEM 330

Topics include medicinal chemistry and molecular pharmacology. The topics will also include a survey of potential drug targets, the molecular interactions between drugs and their targets, the drug discovery and development process and case studies of drugs treating diseases such as cancer, bacterial and viral infection, and neurological disorders.

CHEM 545 Organometallic Chemistry 4R-0L-4C Prereq: CHEM 115, CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 552 Synthetic Organic Chemistry 4R-0L-4C Prereq: CHEM 253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 554 Theoretical Organic Chemistry 4R-0L-4C Prereq: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 555 Natural Products 4R-0L-4C Prereq: CHEM 253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 557 Synthetic Polymer Chemistry 4R-0L-4C Prereq: CHEM 252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 561 Advanced Physical Chemistry 4R-0L-4C Prereq: CHEM 363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 562 Physical Polymer Chemistry 4R-0L-4C Prereq: CHEM 361 or CHE 303

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 570 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses. If cross-listed

with CHEM470, students in CHEM570 will need to complete an additional project.

CHEM 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.

CHEM CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Professors Aidoo, Chapman, Hanson, Kershaw, Lovell, Marincel Payne, Mueller Price, Robinson, and Sutterer.

CE 101 Engineering Surveying 0R-6L2C S Prereq: None

Covers basic principles and practices of surveying. Measurement through the application of surveying techniques; theory of errors and their analysis; concepts of horizontal, vertical, and angular measurement; coordinate systems; basic surveying operations and computations; reading and interpretation of building, highway, and/or bridge plans; traverse computations; applications to construction and design.

CE 111 Geographical Information Systems 2R-0L-2C W Prereq: None

The course covers introductory concepts of geographical information systems and related technologies. Topics covered will relate to the use, collection, creation, and analysis of spatial data in applying GIS and related technologies to civil engineering projects.

CE 250 Sustainable Civil Engineering Design 2R-0L-2C S Prereq: EM 103

An introduction to sustainable design of civil engineering systems. Includes treatment of current issues as they relate to design and construction for economic, environmental and social aspects of civil engineering.

CE 303 Engineering Economy 4R-0L-4C W Prereq: None

Emphasizes time value of money and factors related thereto. Familiarizes students with concepts of annual cost, present worth, and minimum rate of return as tools for consideration of economic factors pertinent to the selection of alternate solutions to engineering problems.

CE 310 Civil Engineering Numerical Methods 2R-0L-2C S Prereq: MA 212

Covers numerical methods used in solution of engineering problems. Typical topics include root finding, numerical integration, numerical differentiation, curve fitting, and numerical solution of ordinary differential equations.

CE 320 Civil Engineering Materials 3R-3L-4C S

A study of the origin, nature, performance and selection criteria of various basic materials used in the practice of civil engineering. These include aggregates, portland cement, concrete, and bituminous materials. Emphasis will be placed on standard methods of testing and characterization as related to the mechanical behavior of materials.

CE 321 Structural Mechanics I 4R-0L-4C F Prereq: EM 203

Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Prereq: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Prereq: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

CE380 Introduction to Transportation Engineering 4R-0L-4C S Coreq: MA223, CE320

Study of transportation functions and transportation systems; measuring and estimating demand; characteristics of transportation modes, interactions between modes, and mode interfaces; social, environmental, technological, economic, and public policy impacts; techniques of transportation system planning, design, and operation, with an emphasis on highway geometric design.

CE 400 Career Preparation Seminar 1R-0L-0C S Prereq: CE 489

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 410 Senior Project 0R-8L-4C On Demand Prereq: Senior class standing

Gives the student the opportunity to work on a civil engineering design or research project of the student's own choice, but which has met the approval of the staff prior to the start of the quarter. Requires presentation of oral and written reports. Not a regular elective offering.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Prereq: CE 321

Matrix methods of structural analysis for two- and three- dimensional indeterminate structures. Force method, stiffness method, introduction to finite element analysis for civil engineers.

CE 430 Structural Design in Timber I 4R-0L-4C On Demand Prereq: CE 321

Presents the analysis and design of modern structures constructed of timber. Considers fasteners and their significance in design. Develops design criteria and their application to plane and three dimensional structures.

CE 431 Structural Design in Steel I 3R-0L-3C S Prereq: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Prereq: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 436 Foundation Engineering 4R-0L-4C S Prereq: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Prereq: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C F Prereq: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 444 Pavement Design and Highway Construction 4R-0L-4C On Demand Prereq: CE 320

Introduction to analysis and design of rigid and flexible pavement systems; subgrade, subbase, base and surfaces; specifications, material testing and construction methods for soil stabilization, flexible and rigid pavements; pavement evaluation, maintenance and reconstruction.

CE 445 Construction Methods and Equipment 4R-0L-4C F Prereq: CE 201 and CE 336, Coreq: CE 442

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Prereq: CE 431 & CE 432

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will also look at environmentally safe and renewable building materials, energy efficient construction techniques, indoor air quality and moisture

problems, etc. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Prereq: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Coreq: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 471 Water Resources Engineering 4R-0L-4C W Prereq: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Geometric Design of Highways and Streets 4R-0L-4C W Pre: CE101 & CE380

Highway planning and design with evaluation of multiple alignment alternatives; geometric design of highways: horizontal and vertical alignment, cross-sectional design; intersection design; earthwork measurements and quantities; reverse curve design; legal aspects of transportation engineering; proper use of the American Association of State Highway and Transportation Officials (AASHTO) design guidelines.

CE 481 Traffic Analysis and Design 4R-0L-4C F Pre: CE380

Study of fundamentals of traffic engineering; components of the traffic system; intersection types and design elements; basic variables of the traffic system (flow, capacity, level of service, delay); design and analysis of traffic signals and intersections; traffic control and traffic impact analysis; safety performance and traffic crash analysis; use of the Highway Capacity Manual and traffic analysis software.

CE 482 Urban Transportation Planning 4R-0L-4C F or W Pre: CE380

Applies general principles of planning, evaluation, selection, adoption, financing, and implementation of alternative urban transportation systems to urban and regional planning; formulation of community goals and objectives, inventory of existing conditions; transportation modeling-trip generation, distribution, modal choice, assignment, technological characteristics and operation of modern transit and other movement systems.

CE 483 Railroad Engineering 4R-0L-4C S Pre: Junior standing or consent of instructor

Provides an overview of rail transportation: history, organizations, economics, safety, freight operations, track-train dynamics, signals and communications, motive power and equipment, track components, construction and maintenance. The basic objective of the course is to gain an understanding of railroads as a transportation industry that merges a number of engineering fields as well as other disciplines that contribute to the success of a complex, growth- oriented industry.

CE 486 Civil Engineering Design & Synthesis I 1R-3L-2C F Prereq: RH 330, CE 460; Coreq: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be initiated by small teams of students to implement principles used in planning, design, and synthesis. Learning objectives include contracting, concept development, concept feasibility, planning and scheduling design work, data collection for subsequent design.

CE 487x Technical System Design & Synthesis 2R-2L-2C W Prereq: CE486; Coeq: CE 488

Technical system design of subdisciplinary elements of civil engineering projects submitted by corporate and governmental sponsors will be completed by individual team members to fulfill the needs of a team project initiated with CE486 and continuing in CE488. The “x” will be used to identify subdiscipline designation (c = general civil design, e= environmental, g = geotechnical, s = structural, t = transportation, w = water resources).

CE 488 Civil Engineering Design & Synthesis II 1R-2L- 2C W Prereq: CE486; Coreq: CE 487

Project management by small teams for civil engineering projects submitted by corporate and governmental sponsors will continue. Learning objectives include coordinate of major design work in subdisciplines, progress reporting to the client, critical path model management to keep the project on schedule to fulfill the needs of a team project initiated with CE486 and continuing in CE487.

CE 489 Civil Engineering Design & Synthesis III 1R-3L-2C S Prereq: CE 487, CE488

Civil engineering projects submitted by corporate and governmental sponsors will be completed. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. Learning objectives include construction planning and cost, final reporting, and public presentation of findings.

CE 490 Directed Studies 1-4C Arranged. F,W,S Prereq: Approval of department head, adviser, and course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

CE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

CE 520 Structural Engineering Practicum 0R-12L-4C Prereq: Grad or consent of instructor

Structural engineering practicum approved by the department.

CE 521 Matrix Methods for Structural Analysis 4R-0L-4C F Prereq: CE 321

Derivation of the direct stiffness method for truss and frame elements. Derivation of the finite element method for 2D plate elements. Requires development of computer programs to implement the direct stiffness method.

CE 522 Structural Dynamics 4R-0L-4C F Pre: Grad or consent of instructor Co-Req: CE 521

Analysis and behavior of structural members and systems subject to dynamic loads including basic theory for single-degree-of-freedom and multi-degree-of-freedom analytical models of civil engineering structures; seismic hazard analysis and methods of analysis for seismic loads; response spectra; time history; and linear and nonlinear methods.

CE 523 Advanced Solid Mechanics 4R-0L-4C W Prereq: Grad or consent of instructor and CE 522 The fundamentals of elasticity are introduced and related to various problems such as beams on elastic foundations, unsymmetrical bending, torsion of thin walled members, and curved beams. Introduction to the analysis and modeling techniques for existing and repaired structures. Design of retrofit measures for a variety of structures using advanced composite materials.

CE 524 Building Design 4R-0L-4C S Prereq: Grad or consent of instructor and CE523

Advanced structural analysis and design concepts for buildings: material nonlinearity, plastic design, pushover analysis, bracing, floor vibrations. Course culminates in a design project.

CE 525 Bridge Engineering 4R-0L-4C S Prereq: CE 321

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Introduces concepts of bridge engineering by providing the students with the necessary knowledge and skills to apply the AASHTO LRFD specifications for the analysis and design of highway and bridge superstructure components.

CE 530 Structural Design in Timber II 4R-0L-4C On Demand Prereq: CE 430

Presents the analysis and design of structures constructed of timber. Tapered beams, curved beams, box beams, stressed-skin panels, tapered columns, built-up columns, laminated arches, plate connected trusses, pole structures, diaphragms, shearwalls.

CE 532 Structural Design in Concrete II 3R-3L-4C F Prereq: CE 432

Advanced topics in reinforced concrete analysis and design such as serviceability. slender columns, two-way slabs, and strut-and-tie modeling.

CE 533 Connections and Detailing 4R-0L-4C S Prereq: CE 431 and CE 432

Analysis and design of structural systems with emphasis on detailing requirements; behavior of bolted and welded connections, including gusset plates, moment-resistant connections, and simple connections; design and analysis of base plate and anchoring systems; and an introduction to seismic detailing requirements.

CE 534 Structural Design in Masonry 4R-0L-4C On Demand Prereq: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C On Demand Prereq: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast

construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Prereq: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 537 Structural Design in Steel II 4R-0L-4C On Demand Prereq: CE 431

Covers the analysis and design of the various elements of a steel structure within the framework of the total structure. Includes composite design, plate girders, and multi-story building frames.

CE 561 Air Pollution 4R-0L-4C W Prereq: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Treatability Studies 2R-6L-4C On Demand Prereq: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 563 Unit Operations in Environmental Engineering 4R-0L-4C F Prereq: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Prereq: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Prereq: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Prereq: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Prereq: CE 471

Environmental planning and management strategies are examined using computer simulation models. Students will be introduced to some of the most widely used models in the fields of hydrology, hydraulics, and stormwater quality (nonpoint source pollution).

CE 568 Applied Contaminant Transport Modeling 4R-0L-4C On Demand Prereq: CE 460 or consent of instructor

Environmental planning and management strategies are examined using computer simulation models. Emphasis is on pollutant transport in various media and emerging pollution issues. Students are introduced to some of the most widely used models in the field of environmental engineering. Students also develop at least one pollutant transport model using common software such as EXCEL, MATHCAD.

CE 569 Environmental Systems Optimization 4R-0L-4C Prereq: Senior or Graduate class standing

Application of the principles of operations research to constrained optimization of environmental systems. Typical topics include strategies for non-linear searches, linear programming, dynamic programming, etc.

CE 570 Fluid Mechanics in Water Resources Engineering 4R-0L-4C On Demand Prereq: CE 371

Presents steady and unsteady flow problems in open channels and pipes, problems dealing with laminar and turbulent boundary layers, and problems including diffusion and dispersion. There will be occasional laboratory work to demonstrate physical modeling in water resources engineering.

CE 571 Environmental River Mechanics 3R-3L-4C S Prereq: CE 371

Concepts of fluvial geomorphology and fluvial hydraulics are examined, including natural stream flow, sediment transport, and ecological processes in alluvial rivers. Students will apply these principles to solve common design problems of channel instability and rehabilitation of impaired streams. Students will visit local streams to perform field data collection of channel geometry, bed and bank material, and water quality.

CE 573 Groundwater Analysis 4R-0L-4C Prereq: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Prereq: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Prereq: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Prereq: Permission of instructor


A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

College & Life Skills

CLSK 100 College and Life Skills 1R-0L-1C F Prereq: None
This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

CLSK 121 College English 4R-OL-4C Prereq: Consent of Instructor
Focuses on understanding the basic patterns and conventions of writing, enhancing reading skills and written comprehension, and improving verbal communication and oral comprehension. This course is intended for students for whom English is a second language. Students required to take CLSK121 must successfully complete the course prior to taking RH131.

CLSK 122 English Language and Culture in Academic Texts 3R-3L-4C Prereq: Consent of instructor required
Reviews English grammar and introduces and develops deeper understanding of academic vocabulary. Familiarizes students with essential essay structures in academia. Introduces academic readings in select topics of academic concern in American socio-culture. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 123 English Language in Academic Research and Composition 3R-3L-4C Prereq: Consent of instructor required
Introduces students to formal research and composition of research papers. Strengthen students' formal research and writing skills for research papers. Guides students through readings in academic journals and articles. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 124 English Language and Culture in Academic Speech, Presentation, and Argumentation 3R-3L-4C Prereq: Consent of instructor required
Emphasizes fluency in spoken English. Rehearses academic vocabulary. Prepares students for academic presentations including technology. Develops students' academic listening and note-taking skills focusing on topics of American socio-cultural study. Introduces students to Socratic discussion and argumentation. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 125 English Rhetoric and Culture in Academia 3R-3L-4C Prereq: Consent of instructor required
Prepares students for full-length lectures in courses related to their majors, focusing on oral rhetoric devices. The course does not satisfy any Rose-Hulman degree requirement.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
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Course Descriptions

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Computer Science & Software Engineering

Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic, ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control.

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prereq: CSSE220 or CSSE221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE 280 Introduction to Web Programming 3R-3L-4C W Prereq: CSSE220 or CSSE221

Introduction to the client-side and server-side mechanisms for creating dynamic web pages with persistent data storage. Browser-webserver interaction via HTTP. Static web page creation using HTML5 and CSS3. Client-side programming using JavaScript, DOM, JSON. Server-side programming and data storage using PHP and MySQL. Asynchronous client-server communication using AJAX and extensions of JavaScript. Session maintenance using cookies. Security considerations. This course provides breadth of knowledge of many tools/technologies rather than deep knowledge of any particular tool/language. No previous experience with web page creation is required.

CSSE290 Special Topics in Computer Science 1 - 4C Arranged Prereq: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prereq: CSSE230 and MA275

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W,S Prereq: CSSE220 or CSSE221, and CSSE132 or CSSE232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prereq: MA275 and CSSE230 (or concurrent enrollment in CSSE230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prereq: CSSE220 or CSSE221, and MA212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 352 Computer Game Development 4R-0L-4C Prereq: CSSE230

An introduction to designing and developing computer games. Topics include game genres, game design, sprites, game physics, collisions, characters, scripting, graphics, and sound. Students will design and implement

their own game using an available game engine.

CSSE 371 Software Requirements Engineering 3R-3L-4C F Prereq: CSSE230, RH330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requ: CSSE371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict management. Professional issues including career planning, lifelong learning, software engineering ethics, and the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prereq: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Design 3R-3L-4C W Prereq: CSSE371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 3R-3L-4C S Prereq: CSSE374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prereq: CSSE230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prereq: CSSE332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prereq: CSSE304

A survey of some current and emerging programming languages, focusing on unique language paradigms—ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prereq: CSSE232, CSSE304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prereq: CSSE230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prereq: CSSE220 or CSSE221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of

the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 433 Advanced Database Systems 4R-0L-4C S Prereq: CSSE333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prereq: CSSE332 and MA275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prereq: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence R-0L-4C Arr Prereq: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prereq: CSSE220 or CSSE221, and MA212 (MA371 or MA373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prereq: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prereq: CSSE230 and MA375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 477 Software Architecture 4R-0L-4C F Prereq: CSSE374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 479 Cryptography 4R-0L-4C S Prereq: CSSE220 or CSSE221, and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 480 Web App Frameworks with AppEngine 3R-3L-4C F Prereq: CSSE230 and CSSE280

Development of desktop and mobile web applications using Google AppEngine. Additional web frameworks include Jinja2, Cloud Datastore, jQuery, Bootstrap, DataTables, Cloud Storage, Cloud Endpoints, and AngularJS. Topics covered using these frameworks include the HTML, CSS, and JavaScript development of client side web apps, sending and receiving REST requests, designing Datastore models, HTML5 and CSS3 features including CSS animations, file storage, Ajax requests, and user OAuth. Emphasis is on hands-on use of these frameworks in web application development. Includes a substantial team project (UI mockups, user stories, development, testing, and presentation).

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prereq: CSSE230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE 483 Android Application Development 4R-0L-4C Prereq: CSSE230

An introduction to programming mobile applications using the Android stack. Topics include the activity lifecycle, resources, layouts, intents for multiple activities, menus, fragments and dialogs, adapters, data persistence via shared preferences, SQLite, and web backends. Emphasis is on hands-on use of these components in application development. Includes a substantial team project (UI mockups, user stories, UML design, development, testing, and presentation).

CSSE 484 iOS Application Development 3R-3L-4C W Prereq: CSSE230

An introduction to programming mobile applications using the iOS stack. Topics include using X-Code for Swift and Objective-C app development, UI components, Storyboards, view controller actions and outlets, table views, navigation controllers, Core Data, and APIs for backend communication. Emphasis is on hands-on use of these components in application development. Includes a substantial team project (UI mockups, user stories, development, testing, and presentation).

CSSE487 Senior Research Project I 4C Arranged Prereq: RH330 and senior standing

CSSE488 Senior Research Project II 4C Arranged Prereq: CSSE487

CSSE489 Senior Research Project III 4C Arranged Prereq: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arranged Prereq: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arranged Prereq: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arranged Prereq: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arranged Prereq: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arranged Prerequisite: RH330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arranged Prerequisite: CSSE494

CSSE 496 Senior Thesis III 4C Arranged Prerequisite: CSSE495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Capstone Project I 4C F Prerequisite: CSSE371 and senior standing

CSSE 498 Senior Capstone Project II 4C W Prerequisite: CSSE 374 and CSSE497

CSSE 499 Senior Capdtone Project III 4C S Prerequisite: CSSE498

For a capstone experience, students work on a team to complete a three-term software engineering project for an approved client. Students choose from two approaches to complete their capstone: 1) Develop a substantive software product, using defensible software processes. The teams focus on delivering key software development, administrative, and user artifacts to the client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure. 2) Investigate a substantive software product or engineering process problem, using a defensible and documented research approach. Tasks include problem analysis, developing alternative solutions, evaluating the solutions via prototyping and iterative processes of investigation, comparing the potential solutions, recording the investigation experience in a research report, and delivering the research artifacts to the client.

CSSE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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News

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Minors

Special Programs

Advanced Placement

Graduate Studies

Electrical & Computer Engineering

Professors Berry, Black, Chang, Doering, Grigg, Herniter, Hoover, Hudson, Kim, Miller, Moore, Mu, Padgett, Rostamkolai, Simoni, Song, Throne, Walter, Wheeler, and Yoder.

ECE 160 Engineering Practice 0R-4L-2C F,W Prereq: none
The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

ECE180 Introduction to Signal Processing 3R-3L-4C F, W, S Pre: MA 111
An introduction to discrete-time signal processing applied to audio, images, and video. Topics include phasor representation of sinusoidal signals, complex arithmetic, sampling, signal spectra, linear time-invariant systems, frequency response, convolution, filter implementation, and MATLAB programming. Integral laboratory.

ECE 203 DC Circuits 3R-3L-4C S,F Prereq: MA111 and PH112
Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

ECE 204 AC Circuits 3R-3L-4C F,W Prereq: PH113 and either ECE203 with a grade of C or better or ES203 with a grade of C or better
Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Circuits and Systems 3R-3L-4C W, S Prereq: MA211, ECE180, and either ECE203 with a grade of C or better or ES203 with a grade of C or better
Introduction to 1st and 2nd order circuits and review of differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C W,S Prereq: MA 211
A course designed for engineers (other than electrical or computer) covering analysis of passive circuits, introduction to op-amps, instrumentation, sinusoidal steady-state, a-c power, and induction motors. EE and CPE majors may not take this course.

ECE 230 Introduction to Embedded Systems 3R-3L-4C W, S Pre: CSSE 120
Sensors and actuators. Input and output devices. Microcontroller architecture. Standard communications protocols. Interrupt generation and processing. Data representation and storage. Memory management. The C programming language and programming styles. Integral laboratory and a term project.

ECE 233 Introduction to Digital Systems 3R-3L-4C F, W Pre: CSSE 120

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

Number systems. Boolean algebra. Combinational logic analysis and design. Logic minimization. Static hazards. Flip-flops, registers, and counters. Sequential logic analysis and design. Finite state machines. Synchronous circuit timing analysis. HDL design and synthesis techniques. Design verification through logic simulation and FPGA implementation. Integral laboratory.

ECE 250 Electronic Device Modeling 3R-3L-4C S, F Pre: ECE204 or ECE205. For non-EE and non-Cpe majors: ES203 with B or better

Introduction to two and three terminal semiconductor devices with a focus on circuit applications. Device characteristics and modeling, circuit application analysis, design, testing, and simulation. Large and small-signal models are introduced in conjunction with circuit analysis and testing. Introduction to wave shaping circuits and to digital and analog applications. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Prereq: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,S Prereq: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Integral laboratory.

ECE 312 Communication Networks 4R-0L-4C W Prereq: MA381, CSSE120

Layered architectures. Circuit and packet switching. The ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Queuing theory. Reliable message transport, internetworking.

ECE 320 Linear Control Systems 3R-3L-4C F,W Prereq: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C W,S Prereq: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C F,S Prereq: CSSE 232

Pipelining, memory hierarchy, peripherals, parallel processing, cost-performance tradeoffs, and a review of new topics in the areas of computer architecture or parallel processing. Computer use, memos, and discussion of current events.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Prereq: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Prereq: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 343 High-Speed Digital Design 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Signal path modeling through connecting lengths of transmission lines with lumped element models of discontinuities. Circuit parameters from geometries and material properties for resistance, capacitance,

inductance and transmission line segments. Lossless and lossy transmission line circuit modeling. High-frequency and high-speed behavior of passive components. Frequency spectrum of digital signals. Digital device driver and receiver modeling. Transmission line impedance discontinuity and termination techniques. Electric and magnetic field coupling mechanisms for capacitive and inductive crosstalk. Ground noise, power plane noise and resonance. Signal and power integrity issues in high-speed digital systems at both the printed-circuit board and chip levels.

ECE 351 Analog Electronics 3R-3L-4C F,W Prereq: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal properties of op-amps. Integral laboratory.

ECE 362 Principles of Design 3R-0L-3C F,S Prereq: ECE204, ECE205, ECE230, ECE233, ECE250 and ECE300

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3R-1L-4C F,S Prereq: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, and wind technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C W,S Prereq: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C F,W Prereq: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE 412 Software Defined Radio 3R-3L-4C S Prereq: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front end, and clock-jitter of the A/D. In the integral laboratory students will use LabVIEW to create a complete digital radio using the NI USRP 2920 platform.

ECE 414 Wireless Systems 4R-0L-4C W Prereq: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Prereq: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with CHE 405, EP 410, and ME 416.

ECE 418 Fiber Optic Systems 4R-0L-4C S Prereq: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing systems, and optical networks. Topics include basic architectures, component overview, system design, and expected degradations along with mitigation techniques. An oral presentation of a technical paper is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for

layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Prereq: ECE 320 or ME 406

Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prereq: ECE 320 or ME 406, Programming proficiency

This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Prereq: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Prereq: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Prereq: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, W Prereq: ECE362

For EE: Prereq or concurrent registration in the remainder of ECE230, ECE310, ECE320, ECE341, ECE351, ECE370 or ECE371, ECE380

For CPE: Prereq or concurrent registration in the remainder of CSSE332 or CSSE230, ECE250, ECE230, ECE312, ECE332, ECE343, ECE380 or ECE320

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W, S Prereq: ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W,S Prereq: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Prereq: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Prereq: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Prereq: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers,

buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Prereq: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/OE 437 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Prereq: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Prereq: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Prereq: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Prereq: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Prereq: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor

Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ME 519, EP 511, and CHE 519.

ECE530 Advanced Microcomputers 3R-3L-4C S Prereq: Graduate standing and ECE 331 or ECE 230; or

ECE 331 or ECE 230 with a grade of B or better; or consent of instructor

32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software debugging tools. Integral laboratory.

ECE534 Advanced Signal and Power Integrity 4R-0L-4C W Prereq: Graduate Standing and ECE341, ECE342, or ECE343; or ECE341, ECE342, or ECE343 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal and power integrity modeling and measurement in high-speed digital systems at IC, PCB, and chassis levels. High-frequency behavior of passive components and packages. Behavior and SPICE models of drivers and receivers. Lossy transmission lines and discontinuity characterization. Mixedmode s-parameters and other network parameters. Frequency and time-domain modeling of capacitive and inductive crosstalk. Differential signaling techniques; timing conventions. Synchronization. Signal equalization. Power plane noise and resonance. High-speed PCB design guidelines. Measurement techniques including time-domain reflectometry, vector network analyzer and impedance analyzer. PCB simulation. Full-wave simulations.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Prereq: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of instructor

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C W Prereq: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Wave-guiding structures, microwave network analysis, scattering parameters, Z, Y and ABCD parameters, passive devices and components, design, fabrication, simulation and measurement of microwave devices and components, matching strategies, multi-conductor transmission lines and crosstalk.

ECE542 Advanced Electromagnetics 4R-0L-4C F Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, EM field theorems, potential functions, power and energy, material properties, wave propagation, reflection and transmission, radiation, scattering, Green's functions, metamaterials and metamaterial-inspired structures, modeling & simulation, measurement technique.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Prereq: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Prereq: Graduate standing and ECE351 and ECE380, or ECE351 and ECE380 with a grade of B or better in both courses, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C S Prereq: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C S Prereq: Graduate standing and ECE351, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Analog signal processing techniques using operational amplifiers. A/D and D/A converters. Protection from electric shock. Measurement of biological potential waveforms (ECG, EMG, EEG, ENG, EOG, ERG). Ultrasound techniques and instrumentation. X-ray CAT techniques. No laboratory, but many in-class demonstrations and emphasis on circuit simulation.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C S Prereq: Graduate standing and ECE 351; or ECE 351 with a grade of B or better; or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE 557 Analog Test and Product Engineering 3R-3L-4C F Prereq: Graduate standing and ECE 300 and ECE 351; or ECE 300 and ECE351 with grades of B or better in both courses; or consent of instructor

Fundamental skills necessary to be an industrial integrated circuit test engineer or product engineer. Includes the economics associated with testing, impact of fabrication variation on devices, instrumentation associated with industrial testing, turning a data sheet into a test plan, industrial testing techniques for analog circuits, trade-offs between test time and test accuracy, statistical analysis of the data and statistical process control, the use of device interface boards necessary to control device loading for different tests. Integral labs with an industrial grade automatic tester (ATE).

ECE580 Digital Signal Processing 4R-0L-4C W Prereq: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Prereq: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE 582/PH 537 Advanced Image Processing 3R-3L-4C Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as PH 537.

ECE 583 Pattern Recognition 3R-3L-4C S Prereq: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 584 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and ECE300, or ECE300 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as BE541.

ECE 597 Special Topics in Electrical Engineering 4C Prereq: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C Arranged

Thesis topic selected in consultation with adviser. Graduate students only.



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Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Engineering Management

EMGT100 Introduction to Entrepreneurship 4R-0L-4C

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

EMGT427 Project Management 4R-0L-4C Undergraduate Only

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4CPre: Junior, Senior,
or consent of instructor

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC Pre: MG 461 or consent of instructor

Air Force ROTC (Military)

Army ROTC (Military)

Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC Pre: MG 462 or consent of instructor

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT511 Graduate Seminar I 1R-0L-1C F

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT512 Graduate Seminar II 1R-0L-1C W

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT513 Graduate Seminar III 1R-0L-1C S

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT514 Graduate Seminar IV 1R-0L-1C Summer

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT520 Accounting for Technical Managers 4R-0L-4C Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership & Organizational Culture 4R-0L-4C Management

This course reviews the management literatures on leadership and organizational culture. It explores that interaction and the range of differences found in practice. Additional topics include: Organizational Change, Vision & Strategy, Business Ethics, and Senge's Learning Organization. Course activities include the 'Winning At Design Automation' simulation that demonstrates cultural issues surrounding rapid growth in a high tech, high commitment company, and The Ethics Challenge game. Students select a company as the topic of their term paper, describing its culture (Schein's approach) and a plan to promote change (Conger's Charismatic Leadership). Students make a 'call to action' speech to convey their leadership plan.

EMGT523 Marketing in New Product Development 4R-0L-4C Management

This course explores marketing concepts and marketing strategy within the context of new product development. Topics addressed include: market research methods, market segmentation, product positioning (4 Ps), pricing strategies, alliances, elasticity, advertising & brands, and the champion role. Student projects define a new product idea, apply course concepts to the development of that idea (segmentation, pricing, etc.) and present their analysis to the class. The course includes the 'NPChallenge'simulation that demonstrates marketing issues an entrepreneur faces in developing a new product.

EMGT524 Production/Operations Management 4R-0L-4C Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-OL-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-OL-4C

This course introduces the concepts of innovation types (radical, incremental, disruptive, open), invention, and diffusion to identify patterns of technology change. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, Delphi, roadmapping, and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-OL-4C Technical or Management

This course presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, estimating, scheduling, Mythical Man Month, Critical Path & Critical Chain, task partitioning & communication, rework, and negotiation. Students apply these concepts in writing case analyses. Typical problems and success factors are discussed in relation to project management choices. Special issues encountered in virtual teams are discussed.

EMGT529 Organizational Behavior 4R-OL-4C

This course will introduce students to principles and theories related to management and organizational behavior. The goal is to transfer or develop knowledge and skills for high performance in a complex technical business environment requiring engineers to make and communicate sound decisions, and react appropriately to unanticipated events. The concepts and techniques for maximizing the effectiveness of engineers in the achievement of organizational and project goals are also emphasized. Topics include power, teaming, motivation, selection, and development while understanding individual characteristics, attitudes, and behaviors. Additionally, we will examine how the use of Emotional Intelligence (EI) will be useful to the advancement of organizations that are culturally diverse.

EMGT531 Economics for Technical Managers 4R-OL-4C Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-OL-4C Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-OL-4C Management

This course presents the Constructivist theory of communication and its application. The culture concept is applied at ethnic (~70%) organizational and interpersonal levels. The course balances theory and application and students write analysis of videos to apply course concepts. Students use Spradley's Ethnoscience approach to conduct interviews and write an ethnography for their term paper. The course helps students to better: develop interpersonal relations, improve their interviewing skills, analyze cultures, and understand diversity across ethnic & gender differences. Concepts include: Culture Shock, Empathy, The Social Construction of Reality, Non Verbal Communication, High & Low Context cultures, M time & P time cultures.

EMGT534 Management Science 4R-OL-4C F (even years) Prereq: Senior or graduate standing Technical or Management

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-0L-4C Management

This course samples the strategy literature and distinguishes economic and managerial (resource based view) perspectives. Strategy issues encountered in transnational management are addressed in cases. Scenario planning is described. Trends and implications of globalization are explored (off shoring, 'rise of the rest', resource use & climate change, BOP, Business Model change) and the 'great recession' is discussed from a long wave perspective. Strategy implementation issues are addressed. Students develop strategies for an organization of their choice and evaluate those strategies using the 'Scenario Strategies' approach in their term paper.

EMGT536 Leadership and Global Challenges 4R-0L-4C

This course examines the art of leadership and its development in our increasingly globalized society. In this course students will apply their general education and use their knowledge, experience, and perspectives learned in a variety of disciplines to investigate the nature and dynamics of leadership. Examining general theoretical approaches, with close attention to the unique challenges which globalization and cross-cultural interactions impose upon leaders, the class will work on three case studies. The first case study focuses on an individual in order to illustrate leadership development. The second will focus on a corporation in order to illustrate mutual influence of leaders, constituents, and organizations. The third will be about an event or a situation which exemplifies the challenges and creativity of leadership in global/transnational/multicultural operations.

EMGT540 Fundamentals of Engineering Management 4R-0L-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT 551 Intellectual Property for Engineers and Scientists 4R-0L-4C Technical or Management Elective

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-0L-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT562 Risk Analysis and Management 4R-0L-4C

This course will introduce students to principles and methods of risk analysis and risk management, as related to diverse engineering and socio-technical systems. Students will learn how to: identify, prioritize and quantify risks; perform qualitative and quantitative risk assessments and develop risk models; assess uncertainty; identify, evaluate, and prioritize risk management alternatives; and communicate risk to stakeholders. Through the use of varied example problems and case studies, students will develop an understanding of the appropriate use of risk analysis and management methods for engineering and policy decision making under uncertainty.

EMGT564 Systems Architecture 4R-0L-4C Prereq: Senior standing or consent of instructor

This class will introduce students to the art and science of systems architecting, where systems architecting refers to uncovering the fundamental structure of a system (functional, physical, logical, operational) defined in terms of system's elements, interfaces, processes, constraints, and behaviors that must operate under specific requirements and constraints. Focus will be placed on investigating the broader meaning of architectures, as they relate to organizations and businesses, in addition to engineered systems and products. Students will be introduced to heuristic and model-based approaches for systems architecting. Through case-studies and example problems in areas of production and manufacturing systems, intelligent transportation systems, social

systems, and others, students will be able to apply the principles, processes and tools of systems architecting in order to structure and support the system development process of a balanced, well-integrated and socially and financially acceptable system.

EMGT567 Economic Analysis of Engineering Projects 4R-0L-4C Prereq: Senior standing or consent of instructor

This class will introduce students to critical principles of economic analysis of engineering projects. In particular, students will explore the process of making economic decisions under the influence of possibly uncertain future conditions and events. These economic decisions might involve investing in new facilities, improving existing production processes, or developing and marketing new products or services in the private and public sectors. Deterministic and multi-attribute evaluation approaches will be discussed. Students will be introduced to methodologies including capital budgeting, cost estimating, various alternative comparison methods, and life cycle costing. Additionally, students will be introduced to the concept of welfare economics through which they will explore economic impacts of infrastructure projects in the public sector. Emphasis will be placed on systems thinking and a systems approach to defining and solving economic problems.

EMGT581 Multi-objective Optimization 4R-0L-4C Prereq: Senior standing or consent of instructor

This course will consider how humans make optimal decisions in an uncertain environment, when they have to simultaneously satisfy multiple objectives/goals under limited resources. Specifically we will consider: how to structure multi-objective problems, different methods and theories of quantifying preferences over multiple objectives a priori or a posteriori, multi-objective optimization methods without preference specification, multi-attribute utility theory, value trade-offs, risk attitudes, and other topics like fuzzy methods. We will also consider the applications of these theories and methods to various problems, including managerial and operational business issues, public policy issues, development of new businesses, etc.

EMGT584 Systems Thinking and Evaluation 4R-0L-4C

This course will focus on applying systems thinking and methodologies, as well as parametric and nonparametric statistical methods to evaluate alternative system designs and design performance measures. Students will learn how to: identify and evaluate system goals, requirements and performance measures; design experiments to assess system performance; apply decision analysis techniques to diverse trade studies; and generate a business case for presenting technical analysis results.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization. Cross-listed with EMGT 486.

EMGT587 Systems Engineering 4R-0L-4C Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Prereq: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.



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Course Descriptions	Advanced Placement
Minors	Graduate Studies

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Engineering Mechanics

All courses in the engineering mechanics area are the responsibility of the Civil and Mechanical Engineering Departments.

EM 101 Statics 2R-0L-2C F Prereq: None

Covers static force analysis. Introduces scalars and vectors with applications to the study of forces, moments, and couples. Stresses free body diagrams with engineering examples.

EM 103 Introduction to Design 1R-3L-2C S Prereq: None

Introduces the engineering design process including problem definition, analysis, alternate solutions, specifications of final solution, and techniques of oral and written communications. Stresses the importance of teamwork through group design efforts.

EM 104 Graphical Communications 1R-2L-2C F Prereq: None

Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication.

EM 120 Engineering Statics 4R-0L-4C F,S Prereq: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, shear and bending moment diagrams, friction, and area moments of inertia. Emphasizes free-body diagrams.

EM 121 Statics and Mechanics of Materials I 4R-0L-4C F,W,S Prereq: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, and strength and elastic deflection of engineering materials due to loads applied axially. Emphasizes free-body diagrams.

EM 202 Dynamics 4R-0L-4C F Prereq: MA 112 and EM 120 or PH 111

Kinematics and kinetics of particles in space and rigid bodies in plane motion. Applications of the principles of Newton's laws, work-energy, impulse-momentum, and conservation laws to solutions of simple two-dimensional dynamics problems.

EM 203 Mechanics of Materials 4R-0L-4C F,W Prereq: EM 120

Strength and elastic deflection of engineering materials due to loads applied axially, in torsion, in bending, and in shear. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 204 Statics and Mechanics of Materials II 4R-0L-4C F,S Prereq: EM 121

Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 301 Fluid Mechanics 4R-0L-4C S Prereq: EM 202

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

EM403 Advanced Mechanics of Materials 4R-0L-4C S Prereq: EM 203 or EM 204

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

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Army ROTC (Military)

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Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Engineering Science

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Multi-Disciplinary Studies

Optical Engineering

Physics

EM 406 Vibration Analysis 4R-0L-4C F Prereq: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

UNDERGRADUATE-GRADUATE COURSES

EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Prereq: ME401 or consent of instructor

Course may be repeated for different topics in fluid mechanics.

EM 502 Advanced Dynamics 4R-0L-4C Prereq: ES 205

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

EM 503 Advanced Vibration Analysis 4R-0L-4C W Prereq: EM 406

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.

EM 505 Theory of Elasticity 4R-0L-4C Prereq: EM 203 or EM 204

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Prereq: EM 403 and MA 330

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.



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Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher,Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W
Scaling laws in small systems; electronics and photonics devices and systems, basics of quantum and statistical mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, Nanophotonics in metals and semiconductors, surface plasmon resonance and applications, photonic bandgap crystals.

EP 290 Directed Study Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 330 Material Failure 3R-3L-4C W Prereq: PH112
Principles of material failure; appearance, physical cause and mathematical description with emphasis on the materials used for micro-scale devices and assemblies. Failure types considered include Rupture, Fatigue, Creep, Corrosion, Electromigration, Electrical Overstress, Electrical Discharge and Thermal. Experiments illustrate the failure type and the machines used to study them. These include Electron, Optical and X-ray microscopes, Spectroscopy and Tension machines. A brief description of the working of each machine will be given.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S
Scaling laws in small systems; mechanical, biological, fluidics, and thermal systems. Nanomaterials and nanofabrication. Nanomechanics: cantilever oscillation, atomic-force microscopy (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors. Nanoscale optics, Nanoscale heat: conduction, convection, and blackbody radiation. Basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise. Cross-listed with EP 506.

EP 407 Semiconductor Fabrication & Characterization 2R-6L-4C F Prereq: PH405 or JR/SR standing & consent of instructor
Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film

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- Army ROTC (Military)
- Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation.

EP 408 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410 or equivalent course

Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-listed with ECE 419, and CHE 419.

EP 415 Engineering Physics Design I 2R-6L-4C S Prereq: OE 280 or EP 280 & JR/SR standing Coreq: RH 330

Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with OE 415.

EP 416 Engineering Physics Design II 2R-6L-4C F Prereq: EP 415

Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with OE 416.

EP 417 Engineering Physics Design III 2R-6L-4C W Prereq: EP 416

Continuation of EP 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with OE 417.

EP 470 Special Topics in Engineering Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 406.

EP 507 Semiconductor Fabrication and Characterization 2R-6L-4C F Prereq: PH405 or consent of instructor

Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-

junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both EP 407 and EP 507.

EP 508 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Science

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 211 Differential Equations (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 212 Matrix Algebra & Systems of Differential Equations (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,

Air Force ROTC (Military)
Army ROTC (Military)
Biology & Biomedical Engineering
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,

- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,
- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Prereq: EM 121, MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better

Extend the conservation and accounting framework to examine fluid motion. Topics include dimensional analysis, pressure variation in both stationary and moving fluids, viscous effects including boundary layers, laminar and turbulent flow. Applications include lift and drag, pipe flow, compressible flow. Fundamental concepts are enriched by laboratory experiences.

ES 203 Electrical Systems 3R-3L-4C F,W,S Prereq: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better; ME 123 or BE 100 or CSSE 120 (or equivalent). Coreq: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Prereq: ES 203 with a grade of C or better, or ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Geology

GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Prereq: CHEM 111
Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology**
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

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Prospective Students

Current Students

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Faculty and Staff

Alumni and Friends

Community Members

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engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F,W,S Prereq: MA113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F,W,S Prereq: MA112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Prereq: MA112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Prereq: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W (odd years) Prereq: MA113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F Prereq: MA113

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F Prereq: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C S Prereq: MA211, MA212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values

problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Prereq: MA211, MA212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA 342 Computational Modeling 4R-0L-4C S Prereq: MA212 and one of CHE310, CE310 ,MA332 or ME323

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 351-6 Problem Solving Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Prereq: MA275 and MA113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Prereq: MA212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Prereq: MA212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Prereq: MA212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Prereq: MA275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Prereq: MA275

An introduction to Group Theory. Topics include: matrix groups, groups of integers modulo a natural number, symmetric and dihedral groups, homomorphisms, subgroups, cosets, quotient groups and group actions. Applications, possibly including games and puzzles, cryptography, and coding theory. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Prereq: Consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F,W,S Prereq: MA113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment

generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C F Prereq: MA381

This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the Central Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Prereq: MA223 or MA382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Prereq: MA223 or MA382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 385

MA 386 Statistical Programming 4R-0L-4C Prereq: previous programming course and either MA223 or MA382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Prereq: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 390 Topics in the Mathematics of Engineering 1-2C Arranged Prereq: consent of instructor

A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

MA 421 Tensor Calculus and Riemannian Geometry 4R-0L-4C Arranged Prereq: MA330

An introduction to the calculus of tensor fields and the local geometry of manifolds. Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

MA 423 Topics in Geometry 4R-0L-4C Arranged Prereq: MA371 or MA373 or consent of instructor

An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C Arranged Prereq: Instructor permission

A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C Arranged Prereq: MA330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to “direct methods.” Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Prereq: MA212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C Arranged Prereq: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 435 Finite Difference Methods 4R-0L-4C W Prereq: MA332 or MA371 or MA373 or MA433

An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Prereq: MA330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green’s function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Prereq: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Prereq: MA212 and one of MA371 or MA373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development “from the ground up.”

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Prereq: MA223 or MA381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Prereq: MA375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C Arranged Prereq: Instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C Arranged Prereq: MA366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C Arranged Prereq: MA366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C Arranged Prereq: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Prereq: MA371 or MA373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Prereq: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C Arranged Prereq: MA375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Prereq: MA375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Prereq: MA375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C Arranged Prereq: MA 378 or MA375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Prereq: CSSE220 and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C Arranged Prereq: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Prereq: MA382, or MA381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Prereq: MA223 or MA382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Prereq: MA212 and either MA223 or MA382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Prereq: MA223 or MA382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics Variable credit Prereq: Consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Prereq: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Prereq: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F,W Prereq: MA492 or permission of the instructor

MA 494 Senior Project III 2C W,S Prereq: MA493

Either participation in a sponsored project or investigation of a problem with a substantial mathematical application, modeling and/or computational content. Students either work individually or in a team typically of 2 or 3, under the supervision of the faculty adviser (course instructor), interacting with the sponsor (if there is one). Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of the Senior Project must be completed in a form acceptable to the adviser and the sponsor if there is one. A submitted written report and public presentation to department are required

MA 495 Research Project in Mathematics Variable credit Prereq: Consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Prereq: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Prereq: MA496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Prereq: MA497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

MA CPT Curricular Practical Training (CPT) 1R-OL-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Prereq: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C Arranged Pre: MA381

Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C Arranged Prereq: MA223 or MA381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Prereq: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Mechanical Engineering

Professors Adams, Bernal, Brackin, Burchett, Cantwell, Chambers, Cornwell, Cunningham, Fine, Fisher, Gibson, Haan, Jones, Kawano, Layton, Lui, McCormack, Mayhew, Mech, Mirth, Moorhead, Moseley, Olson, Onyancha, Purdy, Richards, Sanders, Stamper, White and Winck.

ME 123 Computer Programming 4R-0L-4C F,W,S Prereq: ME/PHOE major or permission of instructor
Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion, presentation software, and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S
Selected student design projects. May include testing and/or computer aided design.

ME 201 Thermodynamics I 4R-0L-4C F Prereq: MA 112
Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Sophomore class standing
Selected student design projects. May include testing and/or computer aided design.

ME 301 Thermodynamics II 4R-0L-4C F,W Prereq: ES 202 or ME 201
Applies property and component background to the analysis of various power and refrigeration cycles. Presents gas and gas-vapor mixtures, psychometric processes, and combustion. Introduces compressible flow.

ME 302 Heat Transfer 4R-0L-4C S,F Prereq: MA 211 and ES 202 or CHE 301 or EM 301
Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Prereq: ES 202
Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Prereq: EM 104
This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Prereq: ME 328
An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering

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- Army ROTC (Military)
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- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Prereq: EM 103, ES 205, MA 223

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Numerical Methods in Engineering 1R-3L-2C W,S Prereq: ME 123, or CSSE 120, MA 212

Engineering problems often lead to analytically intractable equations. This course combines structured programming and applied numerical methods to obtain approximate engineering solutions. Strategies include root finding, numerical integration, finite difference, initial value and boundary value problems. Matlab is used as the programming language for solving iterative problems numerically.

ME 328 Materials Engineering 4R-0L-4C W Prereq: CHEM 111

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Prereq: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 397 Special Topics in Mechanical Engineering 4R-0L-4C

Topics of current interest in mechanical engineering at the 300-level.

ME 401 Foundations of Fluid Mechanics 3R-3L-4C Prereq: ES 202 or EM 301, MA 212

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

ME 402 Advanced Heat Transfer 4R-0L-4C Prereq: ME 302

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

ME 403 Kinematics of Machinery 4R-0L-4C Prereq: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

ME 405 Theoretical Aerodynamics 4R-0L-4C F Prereq: ES 202

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

ME 406 Control Systems 3R-3L-4C F Prereq: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Prereq: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are taken when available.

ME 408 Renewable Energy 4R-0L-4C Prereq: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C S Prereq: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Prereq: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Prereq: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Prereq: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 410, ECE 416, and CHE 405.

ME 417 Advanced Materials Engineering 4R-0L-4C Prereq: ME 328 and EM 203 or EM 204

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ECE 466, CHE 420, and CE 420.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Prereq: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Prereq: EM204

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Prereq: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Prereq: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Prereq: ES 205 or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

ME 430 Mechatronic Systems 3R-3L-4C F,W Prereq: ME 323 or CSSE 220 or ECE 230

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

ME 435 Robotics Engineering 3R-3L-4C S Prereq: ME 430 and Senior class standing

Interdisciplinary course in engineering systems applied to computer controlled automata. Topics include kinematics, control, operation, sensing, and design as applied to various types of industrial and other robots and programmable manipulators. A related project is required.

ME 450 Combustion 4R-0L-4C Prereq: ME 301

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises.

ME 461 Aircraft Design 4R-0L-4C W Prereq: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams.

ME 462 Thermal Design 4R-0L-4C W,S Prereq: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Engineering Design Processes and Methodology 2R-3L-3C F,S Prereq: 3rd qtr junior standing

Design of multi-component systems with consideration of societal and economic factors. Useful design techniques (such as modeling, CPM, optimization, probabilistic approaches, etc.) and factors influencing design (such as human factors, products liability, ethics, safety, etc.) are presented and discussed. Laboratory assignments emphasize case studies. (Students completing ME470 may not receive credit for EMGT 461.)

ME 471 Capstone Design I 1R-6L-3C W Prereq: ME 470, ME 480

Design projects with industry. Students work in teams with three or four members on design projects furnished from external clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in oral presentations and Interim Written Reports which are submitted to the clients.

ME 472 Capstone Design II 1R-6L-3C S Prereq: ME 471

This course is a continuation of ME 471. The student teams continue their design solutions to a general problem furnished by an external client. Continuous and regular communication with the outside clients is expected, as well as with the faculty advisors. During these ten weeks the teams continue refining their solutions, complete the detail design, make oral presentations of the final design, and complete and submit the Final Written Report.

ME 480 Machine Component Design 4R-0L-4C S & F Prereq: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Completion of freshman and sophomore course requirements and approval of adviser and course

instructor

Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Senior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged

Topics of current interests in mechanical engineering.

ME CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

ME 501 Advanced Thermodynamics 4R-0L-4C F Prereq: ME 301 or equivalent

Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.

ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Prereq: ME 302

Course may be repeated for different heat transfer topics.

ME 503 Viscous Fluid Flow 4R-0L-4C Prereq: ME 401

Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.

ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Prereq: ES 205, MA 212

Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.

ME 506 Advanced Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.

ME 507 Applied Nonlinear Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liapunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.

ME 510 Gas Dynamics 4R-0L-4C F Prereq: ES 202

Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer.

ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Prereq: ES 205 and ME 323

Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

ME 512 Light Weight Structures 4R-0L-4C S Prereq: MA 212 and EM 203 or EM 204

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

ME 513 Environmental Noise 4R-0L-4C F Prereq: Senior class standing

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

ME 518 Advanced Kinematics 4R-0L-4C S Prereq: ME 403

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ECE 519, EP 511, and CHE 519.

ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Prereq: EM 104 and Senior class standing

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

ME 522 Advanced Finite Element Analysis 4R-1L-4C S Prereq: ME 422

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

ME 526 Turbomachinery 4R-0L-4C Prereq: ES 205 or equivalent, or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency. Students enrolled in ME 526 must complete a design project including complexities not covered in ME 426. Students may not receive credit for both ME 426 and ME 526

ME 527 Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution. Students enrolled in ME527 must complete a design project not covered in ME 427. Students may not receive credit for both ME 427 and ME 527.

ME 536 Computational Intelligence in Control Engineering 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor

Machine learning and adaptation applied to feedback control, guidance and navigation. Neural Networks for pattern recognition, modeling and control. Radial basis function model identification by recursive least squares. Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.

ME 550 Combustion 4 R-0L-4C Prereq: ME 301

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises. Students enrolled in ME 550 must complete a design project not covered in ME 450. Students may not receive credit for both ME 450 and ME 550.

ME 590 Thesis Research F,W,S

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S



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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Prereq: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

MDS 402 Seminar in Sustainability 2R-0L-2C Pre: Junior class standing and approval of certificate advisors
Provides students with the opportunity to examine, analyze, and reflect upon sustainability and sustainable engineering projects. Course work includes weekly readings and discussions, individual essays, and in-class and public presentations. Enrollment is open to all students, with first priority given to those pursuing the Certificate in Sustainability Studies. Permission to enroll is contingent upon students' previous sustainability project experience (curricular and / or co-curricular) as approved by certificate advisors.

- Air Force ROTC (Military)
- Army ROTC (Military)
- Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
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- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

OE 171 Photography and Holography 2R-0L-2C F
Introduce students to basic knowledge of optics, principles and operation of a camera, shutters, films, and film development, color photography. Basic understanding of interference of waves, concept of holography, properties of various holograms, application of holography, and each student makes an individual hologram that can be seen in sunlight.

OE 172 Lasers and Fiber Optics 2R-0L-2C S
Light, optics, image formation, and optical instruments. Introduction to the properties, physics of operation, types, and applications of lasers. Characteristics of optical fibers and optical communication systems. Applications of lasers and fibers in industry, medicine, and consumer products. Laser safety.

OE 280 Geometrical Optics 3.5R-1.5L-4C W Prereq: PH 113
First-order optics including graphical ray tracing, Gaussian methods, y-nu ray tracing, cardinal points, apertures, stops, pupils, vignetting, and obscuration. Optical invariant, dispersion, chromatic aberrations, glass selection, exact ray tracing, third-order monochromatic aberrations, introduction to computer-aided design and analysis. Relevant laboratory experiments.

OE 290 Directed Research Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 295 Photonic Devices and Systems 3.5R-1.5L-4C S Prereq: PH 113 and MA 211
Optical radiation, radiometry, and photometry. Blackbody radiation and thermal sources. Introduction to optoelectronic devices. Light emitting diodes and other optical sources. Optical detectors (thermal, photoemissive, and semiconductor detectors). Sources/effects of noise and SNR. Flux transfer in optical systems. Relevant laboratory experiments.

OE 360 Optical Materials 4R-0L-4C W Prereq: PH 255 and PH 316
Electromagnetic waves in dielectrics/metals and complex refractive index. Optical, thermal, and mechanical properties of materials. Thin film interference, optical coatings, and design of multilayer films. Optical characterization of materials. Electromagnetic waves in anisotropic materials, double refraction, optical activity, and polarization devices.

OE 392 Linear Optical Systems 4R-0L-4C F Prereq: PH 292 and MA 212
Propagation of light and scalar diffraction theory. Fraunhofer and Fresnel diffraction, coherence, Fourier series and transforms, convolution and correlation. Linear system theory, impulse and step response, transfer functions. Coherent and incoherent image formation, optical transfer function (OTF), modulation transfer function (MTF). Image quality assessment methods. Optical information processing applications.

- Air Force ROTC (Military)
- Army ROTC (Military)
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- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Engineering Science
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Multi-Disciplinary Studies
- Optical Engineering
- Physics

OE 393 Fiber Optics and Applications 3.5R-1.5L-4C W Prereq: OE 295 & PH 316 or ECE 341 or consent of instructor

Basic dielectric waveguide equations; wave optics and ray optics; step-index and graded-index fibers; single mode and multi-mode fibers; mode cutoff conditions; numerical aperture; fabrication of optical fibers; fiber measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems. Relevant laboratory experiments.

OE 395 Optomechanics & Optical Engineering Lab 2R-6L-4C F Prereq: PH 292, OE 280, and OE 295

Design, assembly, and alignment of bench top optical systems. Introduction to experimental techniques in optics. Data collection and analysis. Relevant lecture topics including principles of opto-mechanical design, fold mirrors and prisms, lens and mirror mounting, kinematic mounts, precision adjustments and control.

OE 415 Optical Engineering Design I 2R-6L-4C S Prereq: OE 280 or EP 280 and JR/SR standing Coreq: RH 330

Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415.

OE 416 Optical Engineering Design II 2R-6L-4C F Prereq: OE 415

Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE 417 Optical Engineering Design III 2R-6L-4C W Prereq: OE 416

Continuation of OE 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with EP 417.

OE 434 Non-Imaging Optics 4R-0L-4C S Prereq: OE 295

Lighting, illumination, and solar concentration systems. Radiometry and photometry for illumination, etendue, and concentration. Color coordinates, color vision, and color measurements. Sources, light transfer components, and systems evaluation. Introduction to design methods (edge-ray, compound parabolic concentrator, tailored reflector). Design examples and case studies.

OE 435 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 435.

OE 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments. Cross-listed with ECE 480.

OE 450 Laser Systems and Applications 3.5R-1.5L-4C S Prereq: PH 292 and MA 212

Ray transfer matrix methods, Gaussian beam propagation, and beam quality. Optical resonators and stability, longitudinal and transverse modes. Stimulated emission, population inversion, rate equations, gain and threshold. Q-switching and mode-locking. Applications and types of lasers. Laser safety and relevant laboratory experiments.

OE 470 Special Topics in Optical Engineering 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in optics.

OE 480 Optical System Design 4R-0L-4C F Prereq: OE 280

Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based

optimization, tolerancing, and manufacturing considerations.

OE 490 Directed Research Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S Prereq: OE 393

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments.

OE 495 Optical Metrology 3.5R-1.5L-4C W Prereq: OE 392

Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

OE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Prereq: OE 295, PH 292, PH 316 or SR/GR standing or consent of instructor

Classical optics; exact ray tracing; aberrations, interference, polarization, spatial and temporal coherence; lasers and Gaussian beam propagation; diffraction; optical sources and detectors; selected applications of optics.

OE 535 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 212 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 535.

OE 570 Special Topics in Optics 2 or 4C F,W,S Prereq: OE 295, PH 292, and PH 316

Lectures on special topics in optics such as: optical materials, optics of thin films and infrared optics.

OE 580 Optical System Design 4R-0L-4C F Prereq: OE 280 or SR/GR standing or consent of the Instructor

Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based optimization, tolerancing, and manufacturing considerations. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 480 and OE 580.

OE 585 Electro-Optics and Applications 3R-3L-4C W Prereq: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Students must do additional

project work on a topic selected by the instructor.

OE 592 Fourier Optics and Applications 3 R-3L-4C F Prereq: SR/GR standing or consent of instructor

Two-dimensional linear systems; diffraction theory (Fresnel & Fraunhofer); imaging properties of lenses; frequency analysis of optical imaging systems; spatial filtering; optical information processing; Vander-Lugt filters; wavefront reconstruction; holography; optical computing.

OE 593 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S Prereq: SR/GR standing or consent of instructor

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 493 and OE 593.

OE 594 Guided-Wave Optics 3R-3L-4C S Prereq: OE 485 or SR/GR standing or consent of instructor

Theory of optical waveguides; waveguide modes; fabrication techniques; input and output coupling techniques; waveguide losses; waveguide gratings; electro-optic modulators; integrated optical detectors; applications of integrated optics.

OE 595 Optical Metrology 3.5R-1.5L-4C W Prereq: OE392 or SR/GR standing or consent of instructor; Coreq OE480

Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 495 and OE 595.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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Course Descriptions

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Physics

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

Accelerated Math Physics Program - MA113, PH111, PH112 12R-3L-13C Prereq: One year of college level calculus (BC Calculus or equivalent), one year of high school physics, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Accelerated Math Physics Program Selection Committee.

A 5-week intensive immersion into calculus and physics which covers the equivalent of Calculus III, and Physics I, II. Taught only to incoming freshman who have demonstrated outstanding ability in both calculus and physics. Review of single variable calculus, both differential calculus and integral calculus, as needed. Covers from MA113: vectors and parametric equations in three dimensions, functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems with applications of vectors, parametric equations, partial derivatives and multiple integrals. Covers from PH111, PH112: kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, conservation of energy and momentum, torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, with relevant laboratory experiments.

PH 090 College Preparatory Physics 4R-0L-4C Prereq: College Algebra II
Topics covered include: Units, significant figures, vectors, 1 and 2 dimensional motion; kinematic equations, objects in free-fall, motion in a circle, projectile motion, Newton's Laws, contact forces, non-contact forces: gravity, Coulomb's Law, magnetic force; centripetal force; collisions, linear momentum, rotational kinematics, torques, angular momentum, mechanical equilibrium - static equilibrium. The credits from this course cannot be counted toward any degree completion at Rose-Hulman.

PH 111 Physics I 3.5R-1.5L-4C F,W Coreq: MA 111
Kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, strong and weak nuclear forces, conservation of energy and momentum, relevant laboratory experiments.

PH 112 Physics II 3.5R-1.5L-4C W,S Prereq: PH 111 and MA 111; Co: MA 112
Torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, relevant laboratory experiments.

PH 113 Physics III 3.5R-1.5L-4C S,F Prereq: PH 112 and MA 112; Coreq: MA 113
Sources of magnetic fields, Faraday's law, inductance electromagnetic waves, reflection and polarization, geometric and physical optics, introduction to relativity, relevant laboratory experiments.

PH 200 Career Preparation 1R-0L-1C W,S
This course is for physics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, MA200 and SV200.

PH 215 Introduction to CHAOS 2R-0L-2C W
What constitutes chaotic behavior, detection of chaos in real systems using phase space plots, Poincare

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Army ROTC (Military)
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Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

sections, bifurcation plots, power spectra, Lyapunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Prereq: MA 111, and PH 111 or EM 120

Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Prereq: PH 111 or Coreq: EM 202; and Coreq: MA 112

Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Prereq: MA 111, and PH 111 or EM 120

Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Prereq: MA 111 and PH 111 or EM 120

Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Prereq: PH 113 and Coreq: MA 211

Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Prereq: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Prereq: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Prereq: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Prereq: PH 113

The wave equation; electromagnetic waves; phase and group velocities; complex refractive index; dispersion, interference; interferometers and applications, optical interferometry; coherence; polarized light; Jones vectors/matrices; production of polarized light; birefringence, Fraunhofer diffraction; diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Prereq: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Prereq: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S Arranged Prereq: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W Arranged Prereq: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Prereq: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Prereq: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Prereq: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Prereq: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication, transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Prereq: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Prereq: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schroedinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schroedinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Prereq: PH 113 and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Cross-listed with PH 505.

PH 407 Solid State Physics 4R-0L-4C S (even years) Prereq: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Prereq: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Prereq: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Prereq: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit

hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

PH CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head

Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Prereq: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Prereq: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Prereq: Consent of instructor

Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.



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Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Entrepreneurship Minor

Increasing globalization and the need for rapid implementation of innovations mean that the 21st Century engineers and scientists need to think like entrepreneurs. Everyone does not have to start a technology-based business, but understanding the business requirements of technology commercialization needs to be part of the preparation of technical leaders.

Engineering Management offers an entrepreneurship minor for undergraduates to consider. The program provides the basic tools for making new technology commercially successful.

The requirements of the undergraduate minor are 20 credits of the following:

- Required Courses (8 credits)
- EMGT 330 - Introduction to Engineering Management
 - EMGT 532 - Technical Entrepreneurship

OR

- IA 453 - The Entrepreneur

Choose three of the following courses (12 credits):

- EMGT 520 - Accounting for Technical Managers
 - EMGT 523 - Marketing in New Product Development
 - EMGT 526 - Innovation Management & Forecasting
 - EMGT 527 - Project Management
 - SV 350 - Managerial Accounting
 - SV 356 - Corporate Finance
 - GS 350 - International Trade
 - GS 351 - International Finance

With approval from the Department Head of Engineering Management, course substitutions may be considered for better alignment with a student's professional aspirations. No more than one course may be transferred in to count toward the minor.

For more information contact the Engineering Management Department to discuss this opportunity: MSEM@rose-hulman.edu or 812-877-8822.

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Programs of Study

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

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Applied Biology

The twenty-first century will see unparalleled advances in the biological sciences. Disciplines such as applied biology and biomedical engineering are burgeoning and will greatly impact the way we live in the future. The areas of functional genomics and proteomics will drive discoveries in molecular medicine, gene therapy and tissue engineering. Drug discovery will be facilitated by the elucidation of new target molecules and many pharmaceutical compounds will be produced using biological processes. Environmental management, remediation and restoration will also benefit from advances in applied biology. Biologists will be at the forefront of these advances and will drive the medical, agricultural, environmental and industrial applications of biological sciences.

The applied biology program will produce biologists with the chemistry, mathematics, and physics background needed to solve biotechnological problems in the coming decades. Those students wishing to strengthen their engineering skills can earn the area minor in biomedical engineering. Other students may choose to pursue a second major in Biochemistry and Molecular Biology. The program will prepare graduates for professional careers in government and industrial research laboratories, and in the biotechnology and health-related industries.

Those wishing to continue their studies in graduate or health professions programs will be exceptionally well qualified to do so.

APPLIED BIOLOGY PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
AB 110	Cell Structure and Function	Credit 4	AB 210	Mendelian & Molecular Genetics	Credit 4
CHEM 111	General Chemistry	4	CHEM 251	Organic Chemistry I	3
MA 111	Calculus I	5	CHEM 251L	Organic Chemistry I Laboratory	1
CLSK 100	College & Life Skills	1	PH 111	Physics I	4
Total		14	MA 212	Matrix Algebra and Systems of Differential Equations	4
Winter Term			Winter Term		
AB 120	Comparative Anatomy & Physiology	Credit 4	AB 220	Prokaryotic Cell & Molecular Biology	Credit 4
CHEM 113	General Chemistry II	4	CHEM 252	Organic Chemistry II	3
MA 112	Calculus II	5	CHEM 252L	Organic Chemistry II Lab	1
BE 100	Problem Solving in the Biological Sciences and Engineering	4	PH 112	Physics II	4
Total		17	RH 330	Technical and Professional Communication	4
Spring Term			Total		
AB 130	Evolution and Diversity	Credit 4	16		
CHEM 115	General Chemistry III	4			
MA 113	Calculus III	5			
RH 131	Rhetoric & Composition	4			
Total		17			

Applied Biology

- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

			Spring Term		Credit
			AB 230	Eukaryotic Cell & Molecular Biology	4
			CHEM 253	Organic Chemistry III	3
			CHEM 253L	Organic Chemistry III Lab	1
			PH 113	Physics III	4
			MA 223	Engineering Statistics	4
			Total		16
Junior Year					
Fall Term		Credit			
AB 320	Ecology	4			
CHEM 330	Biochemistry	4			
HSS	Elective	4			
AB 399	Practice of Science	4			
Total		16			
Winter Term		Credit			
AB 330	Evolutionary Biology	4	Senior Year		
AB 496	Senior Thesis Research I	2	Fall Term		Credit
AB	Elective	4	AB 498	Senior Thesis Research III	4
HSS	Elective	4	Science/Technical Elective		4
Total		14	HSS	Elective	4
Spring Term		Credit	Free Elective		4
AB 310	Plant Structure & Function	4	Total		16
AB 497	Senior Thesis Research II	4	Winter Term		Credit
SV 304	Bioethics	4	AB 499	Senior Thesis Research IV	2
HSS	Elective	4	Science/Technical Elective		4
Total		16	AB	Elective	4
			HSS	Elective	4
			Total		14
			Spring Term		Credit
			AB	Elective	4
			Science/Technical Elective		4
			HSS	Elective	4
			Free Elective		4
			Total		16
			Total credits required:		188

An AB science/technical elective is any Rose-Hulman course that has a prefix of AB, BE, CHEM, CHE, CE, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required AB courses	52 credits	Biochemistry & Molecular Biology (Second Major Only) The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility. Two faculty are directly involved with this program: Dr. Mark Brandt, assistant professor of chemistry, is the program coordinator and is a biochemist, and Dr. Richard Anthony, associate professor of applied biology, is a molecular biologist. Many other faculty in both the chemistry and applied biology departments assist with this curriculum.
AB electives	12 credits	
Free electives	8 credits	
HSS electives	24 credits	
Required HSS	12 credits	
Required MA, CHEM, PH	63 credits	
Required CLSK	1 credit	
Sci/Tech electives	12 credits	
Required BE course	4 credits	
Total	188 credits	

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty

supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required Courses

			Elective Courses	
Course	Description	Hours	Choose 12 credits* from the following courses:	
CHEM 111, 113, 115	General Chemistry	12		
CHEM 251, 252, 253	Organic Chemistry	9		
CHEM 251L, 252L, 253L	Organic Chemistry Lab	3	AB 330	Evolutionary Biology
CHEM 330, 430, 433	Biochemistry	9	AB 421	Applied Microbiology
CHEM 361, 362			AB 431	Genomics and Proteomics
or			AB 441	Virology
CHEM 360			AB 451	Cancer Biology
and			AB 492	Directed Study in Applied Biology
CHE 303, 304	Physical Chemistry	8	CHEM 225	Analytical Chemistry
AB 110, 120, 130	Biology	12	CHEM 291	Introduction to Research
AB 210	Genetics	4	CHEM 331	Biochemistry II
AB 220, 230	Molecular Biology	8	CHEM 431	Biochemical Instrumentation
AB 411	Genetic Engineering	4	CHEM 451	Organic Structure Determination
Total		69	CHEM 290	
			or	
			CHEM 490	Chemical Research
			PH 302	Biophysics

Total Credits for Second Major 81

**Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the AB electives listed, and 4 credits chosen from any AB or BE course.*

STUDENTS WITH A MAJOR IN APPLIED BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above AB course (total: 29 hours required beyond Applied Biology major).

Applied Biology Area Minor

The Area Minor in Applied Biology is designed to allow students to enrich studies in their major area. Students wishing to apply another science, mathematics, or engineering discipline to investigate or solve problems in biological systems are encouraged to pursue the Area Minor in Applied Biology. With proper course selection, the Area Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Area Minor in Applied Biology has the following requirements.


1. All students must complete AB110 (Cell Structure and Function) or AB130 (Evolution and Diversity) and at least four more courses in applied biology (AB) or allied areas, above those courses already specifically required to fulfill the student's major.
 - a. At least three of the four electives must be AB courses.
 - b. At least three of the electives must be 200-level or above.Additional courses not listed in the approved allied areas can be considered on a case-by-case basis. See ABBE Department Head.
2. Students electing to pursue the Area Minor in Applied Biology must follow a plan of study that is approved by the Area Minor Advisor. Current advisor information and a form for the planning and approval of an area minor can be obtained from the ABBE Department secretary.
3. Allied area courses could include:
 - BE 310 Analysis of Physiological Systems I
 - BE 320 Analysis of Physiological Systems II
 - BE/MA 482 Bioengineering Statistics
 - BE 570 Introduction to Tissue Engineering
 - CE 460 Introduction to Environmental Engineering
 - CHE 545 Introduction to Biochemical Engineering
 - CHEM 264 Environmental Chemistry
 - CHEM 330 Survey of Biochemistry
 - CHEM 430 Advanced Biochemistry

PH 302 Biophysics
SL 386 Human Evolution
VA 373 Gender Issues

Biochemistry & Molecular Biology Area Minor

Completion of AB110, CHEM111, CHEM113 and CHEM115. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

- AB 210 Mendelian and Molecular Genetics
- AB 220 Prokaryotic Cell and Molecular Biology
- or
- AB 230 Eukaryotic Cell and Molecular Biology
- AB 411 Genetic Engineering
- or
- AB 431 Genomics and Proteomics
- CHEM Introduction to Organic Chemistry and
- 230 Biochemistry
- or
- CHEM Organic Chemistry I
- 251
- and
- CHEM Organic Chemistry II
- 252
- CHEM Biochemistry
- 330
- CHEM Advanced Biochemistry
- 430
- with
- CHEM Biochemistry Laboratory
- 433



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Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Biochemistry

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

BIOCHEMISTRY PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term		Credit	Year		Credit
CHEM 111*	General Chemistry I	4	Fall Term		
MA 111	Calculus I	5	CHEM 251	Organic Chemistry I	3
AB 110	Cell Structure & Function	4	CHEM 251L	Organic Chemistry I Lab	1
CLSK 100	College & Life Skills	1	PH 113	Physics III	4
RH 131	Rhetoric and Composition	4	MA 212	Matrix Algebra and	4
	or			Systems	
HSS	Elective			of Differential Equations	
	Total	18	AB 210	Mendelian &	4
Winter Term		Credit		Molecular Genetics	
CHEM 113*	General Chemistry II	4		Total	16
MA 112	Calculus II	5	Winter Term		Credit
PH 111	Physics I	4	CHEM 200	Career Preparation	1
RH 131	Rhetoric and Composition	4		(take in winter or spring)	
	or		CHEM 252	Organic Chemistry II	3
HSS	Elective		CHEM 252L	Organic Chemistry II Lab	1
	Total	17	CHEM 291	Intro to Undergraduate	4
Spring Term		Credit		Research	
CHEM 115	General Chemistry III	4	MA 381	Introduction to Probability	4
MA 113	Calculus III	5		with Applications to	
PH 112	Physics II	4		Statistics	
HSS	Elective	4	AB 220	Prokaryotic Cell &	4
	Total	17		Molecular Biology	
				Total	16 or
					17
			Spring Term		Credit

- | |
|------------------------|
| Applied Biology |
| Biochemistry |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- | |
|---|
| Aerospace Studies (Air Force ROTC) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS)
(Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Military |
| Pre-Professional Programs |

			CHEM 200	Career Preparation	1
				(take in winter or spring)	
Junior Year					
<i>Fall Term</i>		<i>Credit</i>	CHEM 253	Organic Chemistry III	3
CHEM 326	Bioanalytical Chemistry	4	CHEM 253L	Organic Chemistry III Lab	1
CHEM 330	Biochemistry I	4	CHEM 225	Analytical Chemistry	4
CHEM 361	**Physical Chemistry I	4	AB 230	Eukaryotic Cell &	4
HSS	Elective	4		Mol. Biology	
	Total	16	HSS	Elective	4
<i>Winter Term</i>		<i>Credit</i>		Total	16 or 17
CHEM 327	Advanced Analytical	4			
CHEM 362	**Physical Chemistry II	4			
CHEM 331	Biochemistry II	4			
CHEM 400	Chemical Communication I	1			
HSS	Elective	4			
	Total	17			
			Senior Year		
<i>Spring Term</i>		<i>Credit</i>	<i>Fall Term</i>		<i>Credit</i>
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4	CHEM 441	Inorganic Chemistry I	4
CHEM 430	Advanced Biochemistry	4	CHEM 401	Chemical Communication II	1
CHEM 433	Biochemistry Lab	1	CHEM 490	Chemistry Research	1
HSS	Elective	4		##Advanced Chemistry or Biochemistry Elective	4
CHEM 490#	Research	1		Advanced Biology Elective	4
	Total	14		Free Elective	4
				Total	18
			<i>Winter Term</i>		<i>Credit</i>
			CHEM 402	Chemical Communication III	1
			CHEM 490	Chemistry Research	1
			HSS	Elective	4
				##Advanced Biology, Chemistry, Biochem	4
				Free Elective	
				Total	14
			<i>Spring Term</i>		<i>Credit</i>
			CHEM 403	Chemical Communication IV	1
			CHEM 490	Chemistry Research	1
				HSS Elective	4
				Free Elective	4
				Free Elective	4
				Total	14
			Total credits required:		194

Notes: Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM111 General Chemistry I is an automatic substitution for the former CHEM105 Engineering Chemistry I.

CHEM113 General Chemistry II is an automatic substitution for the former CHEM107 Engineering Chemistry II.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

			Summary of minimum graduation requirements:			
Course	Numbers	Credits				
General Chemistry	111, 113, 115	12	Course or areas	Required	Elective	Total
Organic Chemistry	251, 252, 253	12				
Analytical Chemistry	225, 326, 327	12				
			Chemistry	78	8	86

Physical Chemistry	361, 362, 363	12	Physics	12	0	12
Inorganic Chemistry	441	4	Mathematics	23	0	23
Biochemistry	330, 331, 430, 433	13	Biology	20	0	20
Research	291, 490	8	Humanities and Social	4	32	36
Chemical Communication	400, 401, 402, 403	4	Sciences			
Career Preparation	200	1	Electives	0	16	16
Electives		8	College and Life Skills	1	0	1
Total		86	Total	136	56	194


Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
*CHEM111	General Chemistry I	4
*CHEM113	General Chemistry II	4
*CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		32

*CHEM 105 and CHEM 107 can be substituted for CHEM111You may replace CHEM111, CHEM 113, and CHEM 115.

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	
or CHEM253	Organic Chemistry III	4
CHEM330	Biochemistry I	
or CHEM361	Physical Chemistry I	4
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24

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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

- be able to design and conduct experiments, making measurements from both living and non-living systems.
- be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- be able to function in multidisciplinary teams in different roles.
- be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- have the skills required for self-learning.
- be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
AB 110	Cell Structure and Function	4	ES 201	Conservation & Accounting Principles	4
PH 111	Physics I	4	CHEM 111	General Chemistry I	4
MA 111	Calculus I	5	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	ES 203	Electrical Systems	4
EM 104	Graphical Communication	2		Total	16
	Total	16			
Winter Term		Credit	Winter Term		Credit
AB 120	Comparative Anatomy & Physiology	4	ES 202	Fluid and Thermal Systems	3
PH 112	Physics II	4	ES 204	Mechanical Systems	3
MA 112	Calculus II	5	MA 212	Matrix Algebra and Systems of Differential Equations	4
BE 100	Problem Solving in the Biological Sciences and Engineering	4	CHEM 113	General Chemistry II	4
	Total	17	HSS	Elective	4
			Total		18
Spring Term		Credit	Spring Term		Credit
PH 113	Physics III	4	BE 201	Biomedical Measurements	4
RH 131	Rhetoric & Composition	4	AB 130	Evolution and Diversity	4
MA 113	Calculus III	5	ES 205	Analysis & Design of Engineering Systems	4
EM 121	Statics and Mechanics of Materials I	4	MA 223	Engineering Statistics	4
	Total	17	Total		16
Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
HSS	Elective	4	BE 410	Biomedical Engineering Design I	4
AB 205	Cellular Physiology	4			
	Tech & Profess'l Comm	4	HSS	Elective	4
HSS or RH330	or HSS Elective				
EM 204	Statics and	4		Free Elective	4

	Mechanics of Materials II		BE	Area Elective	4
	Total	16		Total	16
Winter Term		Credit	Winter Term		Credit
BE 310	Physiological Systems I	4	BE 420	Biomedical Engineering	4
BE 331	Biomechanics	3		Design II	
BE 351	Biomedical Engineering Lab	2	HSS	Elective	4
BE 361	Biomaterials	3		Free Elective	4
HSS or RH330	HSS Elective or	4	BE	Area Elective	4
	Tech & Profess'I Comm			Total	16
	Total	16	Spring Term		Credit
Spring Term		Credit	BE 430	Biomedical Engineering	2
SV 304	Bioethics	4		Design III	
BE 320	Physiological Systems II	4	HSS	Elective	4
BE 390	Principles of Biomedical	2		Free Elective	4
	Engineering Design		BE	Area Elective	4
BE	Area	4		Total	14
	Total	14	Total credits required:		192

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the ABBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

- CourseTitle
- BE 417Advanced Materials
- BE 516Introduction to MEMS
- BE 539Multiscale Biomechanincs
- BE 560Tissue-Biomaterial Interactions
- BE 570Introduction to Tissue Engineering
- CHE 315*Materials Science and Engineering
- CHE 441Polymer Engineering
- ME 317** Design for Manufacturing
- and
- BE 317** Design for Biomedical Manufacturing
- ME 328* Materials Engineering

*CHE 315 OR ME 328 may be used, but not both

**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

- CourseTitle
- BE 340Biomedical Instrumentation and Signal Processing
- BE 350Biocontrols
- BE 516Introduction to MEMS
- BE 435/535Biomedical Optics
- BE 555Electrophysiology
- ECE 230Microcontrollers and Computer Architecture
- ECE 480Introduction to Image Processing
- ME 430Mechatronic Systems
- BE 541Medical Imaging
- BE 543Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course Title

- ME 317**Design for Manufacturing
and
BE 317** Design for Biomedical Manufacturing
BE 525 Biomedical Fluid Mechanics
BE 531 Biomechanics II
BE 534 Soft Tissue Mechanics
BE 539 Multiscale Biomechanics
BE 545 Orthopaedic Biomechanics
BE 550 Research Methods in Biomechanics
EM 403 Advanced Mechanics of Materials
ME 422 Finite Elements for Engineering Applications
ME 520 Computer-Aided Design and Manufacturing
ME 522 Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Area Minor

The biomedical engineering area minor is intended to provide a strong biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and the health care related fields.

In order to complete the requirements in the biomedical engineering area minor, a student must complete AB110 "Cell Structure and Function" and 16 credits from list shown below. At least three of the courses must have a BE prefix.

Biomedical Engineering Minor Electives

PH 302	4	Biophysics
AB 411	4>	Genetic Engineering
BE 310	4	Analysis of Physiological Systems I
BE 320	4	Analysis of Physiological Systems II
BE 331		Biomechanics
BE 340	4	Biomedical Instrumentation
BE 350	4	Biocontrol Systems
BE 351	2	Biomedical Engineering Lab *
BE 352	1	Biomechanics Lab *
BE 353	1	Biomaterials Lab *
BE 361	3	Biomaterials
BE 435/5354		Biomedical Optics
BE 482	4	Bioengineering Statistics
BE 510	4	Biomedical Signal and Image Processing
BE 525	4	Biomedical Fluid Mechanics
BE 531	4	Biomechanics II
BE 534	4	Soft Tissue Mechanics
BE 539	4	Multiscale Biomechanics
BE 541	4	Medical Imaging
BE 543	4	Neuroprosthetics
BE 545	4	Orthopaedic Biomechanics
BE 550	4	Research Methods in Biomechanics

BE 555	4	Electrophysiology
BE 560	4	Tissue-Biomaterial Interactions
BE 570	4	Introduction to Tissue Engineering


*Students getting credit for BE351 cannot get credit for BE352 or BE353.

In addition to courses on the above list, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

Basic Engineering Courses

- EM 121 Statics and Mechanics of Materials I
- EM 204 Statics and Mechanics of Materials II
- EM 301 Fluid Mechanics
- ECE 130Introduction to Logic Design
- ECE 200Circuits & Systems
- ES 201 Conservation & Accounting Principles
- ES 202 Fluid & Thermal Systems
- ES 203 Electrical Systems
- ES 204 Mechanical Systems
- CHE 201Conservation Principles and Balances
- CHE 202Basic Chemical Process Calculations
- CHE 301Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the Head of the Department of Applied Biology and Biomedical Engineering.



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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

- Our graduates will attain a promotion and/or responsibilities beyond their entry-level position, or progress toward the completion of an advanced degree.
- Our graduates will continue to develop professionally.
- Our graduates will collaborate professionally within or outside of their organizations at a regional, national and/or international level.
- Our graduates will participate in service to their professions and/or community organizations.

Student Outcomes

Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

11. A knowledge of contemporary issues

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)			Freshman Year (A2 Schedule)		
Fall Term		Credit	Fall Term		Credit
CHEM 111	General Chemistry I*	4	CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1	CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2	EM 104	Graphical Communications	2
MA 111	Calculus I	5	MA 111	Calculus I	5
RH 131	Rhetoric & Composition	4	RH 131	Rhetoric & Composition	4
Total		16	Total		16
Winter Term		Credit	Winter Term		Credit
CHEM 113	General Chemistry II*	4	CHEM 113	General Chemistry II*	4
MA 112	Calculus II	5	MA 112	Calculus II	5
PH 111	Physics I	4	PH 111	Physics I	4
HSS	Elective	4	HSS	Elective	4
Total		17	Total		17
Spring Term		Credit	Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2	CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4	CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2	EM 103	Introduction to Design	2
MA 113	Calculus III	5	MA 113	Calculus III	5
PH 112	Physics II	4	PH 112	Physics II	4
Total		17	Total		17
Sophomore Year (A1 Schedule)			Sophomore Year (A2 Schedule)		
Fall Term		Credit	Fall Term		Credit
CHE 200	Career Preparation I	0	CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4	CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3	CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1	CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4	MA 211	Differential Equations	4
EM 101	Statics I	2	EM 101	Statics I	2

	Total	14		Total	14
<i>Winter Term</i>		<i>Credit</i>	<i>Winter Term</i>		<i>Credit</i>
CHE 202	Basic Chemical Process Calculations	4	CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3	CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1	CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4	MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4	HSS	Elective	4
	Total	16		Total	16
<i>Spring Term</i>		<i>Credit</i>	<i>Spring Term</i>		<i>Credit</i>
CHE 301	Fluid Mechanics	4	MA 223	Engineering Statistics I	4
CHE 303	Chemical Engineering Thermodynamics	4	CHEM 225	Analytical Chemistry I	4
	Elective (Approved)	4	HSS	Elective	4
HSS	Elective	4	CHE 315	Materials Science	4
	Total	16		Total	16

Junior

Year

(A1

Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
CHE 315	Materials Science	4
CHEM 225	Analytical Chemistry I	4
	Total	16
<i>Winter Term</i>		<i>Credit</i>
CHE 321	Applications of Heat and Mass Transfer	4
CHEM 360	Intro Physical Chemistry	4
MA 223	Engineering Statistics I	4
RH 330	Technical and Professional Communication	4
	Total	16
<i>Spring Term</i>		<i>Credit</i>
CHE 404	Kinetics & Reactor Design	4
CHE 411	Chemical Engineering Lab I	3
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
	Total	15

Senior Year

(A1 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4
CHE 416	Design I	4
	Free Elective(Free)	4
	Free Elective(CHE)	4
	Total	17
<i>Winter Term</i>		<i>Credit</i>

Junior

Year

(A2

Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
RH 330	Technical and Professional Communication	4
	Total	16
<i>Winter Term</i>		<i>Credit</i>
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
	Total	16
<i>Spring Term</i>		<i>Credit</i>
CHE 321	Applications of Heat and Mass Transfer	4
CHE 411	Chemical Engineering Lab I	3
CHEM 360	Intro Physical Chemistry	4
HSS	Elective	4
	Total	15

Senior Year

(A2 Schedule)

<i>Fall Term</i>		<i>Credit</i>
CHE 404	Kinetics & Reactor Design	4
CHE 409	Professional Practice	1
CHE 412	Chemical Engineering Lab II	4
CHE 416	Design I	4
	Free Elective(Free)	4
	Total	17
<i>Winter Term</i>		<i>Credit</i>

CHE 413	Chemical Eng. Lab III	4	CHE 413	Chemical Eng. Lab III	4
CHE 417	Design II	4	CHE 417	Design II	4
CHE 440	Process Control	4	CHE 440	Process Control	4
HSS	Elective	4	HSS	Elective	4
	Total	16		Total	16
<i>Spring Term</i>		<i>Credit</i>	<i>Spring Term</i>		<i>Credit</i>
CHE 418	Design III	2	CHE 418	Design III	2
HSS	Elective	4	HSS	Elective	4
HSS	Elective	4		Elective(CHE)	4
	Elective(Approved)	4		Elective(CHE)	4
	Elective(CHE)	4		Elective(Approved)	4
	Total	18		Total	18
Total credits required:		194	Total credits required:		194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 405 Introduction to MEMS: Fabrication and Applications
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Area Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students

majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 320 Fundamentals of Heat and Mass Transfer
- CHE 321 Applications of Heat and Mass Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Area Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- AB110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology
- or
- AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering
- AB421 - Applied Microbiology
- AB431 - Genomics and Proteomics
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary

AREA OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. Students may not count courses towards a concentration that also count towards another concentration or towards a minor, certificate, double major, or second degree. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics

- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 450 Air Pollution
- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT534 Management Science
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include applied biology, chemical engineering and mathematics.

CHEMISTRY PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
		Credit			Credit
CHEM 111*	General Chemistry	4	CHEM 251	Organic Chemistry I	3
MA 111	Calculus I	5			
AB 110**	Cell Structure and Function	4	CHEM 251L	Organic Chemistry I Lab	1
CLSK 100	College & Life Skills	1	PH 113	Physics III	4
RH 131	Rhetoric and Composition	4	MA 212	Matrix Algebra and Systems	4
HSS	Elective			of Differential Equations	
	Total	18		Free Elective	4
Winter Term			Year		
		Credit			Credit
CHEM 113*	General Chemistry II	4	CHEM 200	Career Preparation	1
MA 112	Calculus II	5		(take in winter or spring)	
PH 111	Physics I	4	CHEM 252	Organic Chemistry II	3
RH 131	Rhetoric and Composition	4			
HSS	Elective		CHEM 252L	Organic Chemistry II Lab	1
	Total	17	CHEM 291	Intro to Undergraduate Research	4
Spring Term			Year		
		Credit			Credit
CHEM 115	General Chemistry III	4	MA 381	Introduction to Probability	4
MA 113	Calculus III	5		with Applications to	
HSS	Elective	4		Statistics	

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

PH 112	Physics II	4	Free Elective	4
	Total	17	Total	16 or 17
			<i>Spring Term</i>	<i>Credit</i>
			CHEM 200	Career Preparation
				(take in winter or spring)
			CHEM 253	Organic Chemistry III
				3
Junior Year				
<i>Fall Term</i>		<i>Credit</i>		
CHEM 326	Bioanalytical Chemistry	4	CHEM 253L	Organic Chemistry III Lab
CHEM 361	***Physical Chemistry I	4	CHEM 225	Analytical Chemistry I
CHEM 330	Biochemistry I	4	HSS	Elective
HSS	Elective	4		Free Elective
	Total	16		4
			Total	16 or 17
<i>Winter Term</i>		<i>Credit</i>		
CHEM 327	Advanced Analytical	4		
CHEM 362	***Physical Chemistry II	4		
CHEM 400	Chemical Communications I	1		
HSS	Elective	4		
	Free Elective	4		
	Total	17		
<i>Spring Term</i>		<i>Credit</i>		
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4		
CHEM 451	Organic Structure Determination	4		
HSS	Elective	4		
	Free Elective	4		
CHEM 490#	Research	1		
	Total	17		
			Senior Year	
			<i>Fall Term</i>	<i>Credit</i>
			CHEM 441	Inorganic Chemistry I
			CHEM 401	Chemical Communications II
			CHEM 490	Research
				Chemistry Elective
				Free Elective
			Total	14
			<i>Winter Term</i>	<i>Credit</i>
			CHEM 442	Inorganic Chemistry II
			CHEM 402	Chemical Communications III
			CHEM 490	Research
			HSS	Elective
				Chemistry Elective
				(400-level)###
			Total	14
			<i>Spring Term</i>	<i>Credit</i>
			CHEM 403	Chemical Communications IV
			CHEM 490	Research
			HSS	Elective
				Free Elective
				Free Elective
			Total	14
			Total credits required:	193

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM111 General Chemistry I is an automatic substitution for the former CHEM105 Engineering Chemistry I.

CHEM113 General Chemistry II is an automatic substitution for the former CHEM107 Engineering Chemistry II.

*AB120 or AB130 may be substituted for AB110

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

			Summary of minimum graduation requirements:		
Course	Numbers	Credits	Course or areas	Required	ElectiveTotal
General Chemistry	111, 113, 115	12	Chemistry	77	8 85
Organic Chemistry	251, 252, 253	12	Physics	12	0 12
Analytical Chemistry	225, 326, 327	12	Mathematics	23	0 23
Physical Chemistry	361, 362, 363	12			
Inorganic Chemistry	441, 442	4			

Biochemistry	330	4	Biology	4	0	4
Organic Structure Determination	451	4	Humanities and Social Sciences	4	32	36
Chemical Communication	400, 401, 402, 403	4	Electives	0	32	32
Research	291, 490	8	College and Life Skills	1	0	1
Career Preparation	200	1	Total	121	76	193
Electives		8				
Total		85				

Area Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The

student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in applied biology or chemical engineering are different from those majoring in other disciplines.

Area Minor in Chemistry for Most Students

Course Number	Course Title	Credits	*Approved list of chemistry electives includeCHEM253, CHEM290 (up to two credit hours), CHEM291, or any 300 or 400 level chemistry courses.		
CHEM113	General Chemistry II	4	Area Minor in Chemistry for Chemical Engineering and Applied Biology Majors		
CHEM115	General Chemistry III	4			
CHEM225	Analytical Chemistry	4			
CHEM251	Organic Chemistry I	4			
CHEM252	Organic Chemistry II	4			
	*Approved List of Chemistry Electives	4	Course Number	Course Title	Credits
			CHEM225	Analytical Chemistry	4
			CHEM253	Organic Chemistry III	4
Total		24		Chemistry Electives*	12
			Total		20

*The electives cannot count toward the student’s major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits	Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors		
CHEM111	General Chemistry I	4	Environmental Certificate for Chemistry and Biochemistry Majors		
CHEM113	General Chemistry II	4			
CHEM115	General Chemistry III	4			
CHEM225	Analytical Chemistry	4			
CHEM251	Organic Chemistry I	4			
CHEM264	Introduction to Environmental Science	4	Course Number	Course Title	Credits
CHEM 371	Environmental Analytical Chemistry	4	CHEM225	Analytical Chemistry	4
CHEM 465	Energy and the Environment	4	CHEM253	Organic Chemistry III	4
Total		32	or	Biochemistry	
			CHEM330		
			CHEM361	Physical Chemistry I	4
			or	Chemical Engineering	
			CHE303	Thermodynamics	
			CHEM264	Introduction to Environmental Science	4
			CHEM371	Environmental Analytical Chemistry	4
			CHE 465	Energy and the Environment	4
			Total		24



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society's need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department's Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department's Program Educational Objectives and Student Learning Outcomes*

Program Educational Objectives

- I. Graduates will demonstrate the ability to perform **essential engineering functions** in the design, management, or construction industry.
- II. Graduates will demonstrate the ability to **design/construct complex engineering systems** in the broad-based engineering industry.
- III. Graduates will demonstrate their potential for **technical leadership and management**.

Student Learning Outcomes

1. **Technical Core** - Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
2. **Experiments** - Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.
3. **Engineering Problems** - Develop problem statements and solve well-defined engineering problems in

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

four technical areas appropriate to civil engineering.

- 4. **Engineering Impact** - Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- 5. **Contemporary Issues** - Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.
- 6. **Design** - Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- 7. **Multidisciplinary** - Function effectively as a member of a multidisciplinary team.
- 8. **Professional/Ethical** - Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- 9. **Communication** - Organize and deliver effective verbal, written, and graphical communications.
- 10. **Engineering Tools** - Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.
- 11. **Life Long Learning** - Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- 12. **Leadership** - Apply leadership principles to direct the efforts of a small group.
- 13. **Service** - Use one's time and skills to benefit an individual or community without cost to the recipient.
- 14. **Project Management** - Explain key concepts in project management, and develop solutions to well-defined project management problems.
- 15. **Business and Public Administration** - Explain key concepts and processes used in business, public policy, and public administration.
- 16. **Cultural and Global Awareness** - Analyze and interpret cultural perspectives and social systems that define human characteristics.

* The civil engineering program uses the term "educational objective" to describe the expected accomplishments of our students in three to five years following graduation. The term "student learning outcome" is used to describe knowledge and skills at the time of graduation.

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Civil Engineering PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	5	Fall Term		
PH 111	Physics I	4	MA 211	Differential Equations	4
RH 131	Rhetoric and Composition	4	CHEM 111	General Chemistry I	4
	or		EM 202	Dynamics	4
	Elective(HSS)		HSS	Elective	4
CLSK 100	College & Life Skills	1		Total	16
EM 104	Graphical Communications	2	Winter Term		
	Total	16	MA 212	Matrix Algebra and	4
Winter Term				Systems	
MA 112	Calculus II	5		of Differential Equations	
PH 112	Physics II	4	EM 203	Mechanics of Materials	4
RH 131	Rhetoric and Composition	4	CHEM 113	General Chemistry II	4
	or		HSS	Elective	4
	Elective(HSS)			Total	16
CE 111	Geographic Info Systems	2	Spring Term		
	Total	15	MA 223	Statistics for Engineers	4
Spring Term			EM 301	Fluid Mechanics	4
MA 113	Calculus III	5	CE 250	Sustainable Civil	2
EM 103	Introduction to Design	2		Engineering Design	
EM 120	Engineering Statics	4	CE 320	C.E. Materials	4
CE 101	Engineering Surveying I	2	CE 380	Transportation Engineering	4
	Elective (Science)	4		Total	18
	Total	17			

Junior Year

Senior Year

Fall Term			Credit	Fall Term			Credit
CE 321	Structural Mechanics I		4	CE 486	C.E. Design & Synthesis I		2
CE 336	Soil Mechanics		4				
ME 201	Thermodynamics		4	CE	**C.E. Elective		4
	or			CE 450	C.E. Codes & Regulations		4
CHE 201	Conservation Principles and Balances			HSS	Elective		4
				HSS	Elective		4
CE 371	Hydraulic Engineering		4		Total		18
	Total		16	Winter Term			Credit
Winter Term			Credit	CE 487	Technical System Design & Synthesis		2
ECE 206	Elements of Electrical Eng.		4	CE 488	C.E. Design & Synthesis II		2
	or			CE	**C.E. Elective		4
CHE 202	Basic Chemical Process Calculations				*Elective (Technical)		4
CE 441	Construction Engineering		2	CE 303	Engineering Economy		4
CE 432	Concrete Design I		3		Total		16
CE 471	Water Resources Engineering		4	Spring Term			Credit
	Elective (Science)		4	CE 489	C.E. Design & Synthesis III		2
	Total		17		*Elective(Technical)		4
Spring Term			Credit	HSS	Elective		4
CE 310	Civil Engineering Numerical Methods		2	HSS	Elective		4
CE 431	Steel Design I		3	CE 400	Career Preparation Seminar		0
CE 460	Environmental Engineering		4		Total		14
RH 330	Technical and Professional Communication		4		Total credits required:		194
CE 461	Environmental Engineering Lab		2				
	Total		15				

***A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, or physics.**

****Student shall choose any 400 or 500 level CE elective course, designated with the "CE" prefix, as a CE Elective, in consultation with their advisor.**

Environmental Engineering Area Minor

The Environmental Engineering Area minor includes 6 required courses and 8 elective credit hours. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their interests.

The 6 required courses are as follows:

CE 460	Introduction to Environmental Engineering
CE 471	Water Resources Engineering
CHEM 264	Introduction to Environmental Science
CE 563/CHE 461	Unit Operations in Environmental Engineering
CE 564	Aquatic Environmental Chemistry
CHEM 251	Organic Chemistry I
CHEM 251L	Organic Chemistry I Laboratory

And 8 credit hours from the following courses:

CE 561/CHE 450	Air Pollution Control
CE 562	Treatability Studies
CE 565	Solid and Hazardous Waste Regulation and Treatment
CE 566	Environmental Management
CE 567	Applied Hydrologic Modeling
CE 568	Applied Contaminant Transport Modeling
CE 569	Environmental Systems Optimization

CE 573	Groundwater Analysis
CE 590	Special Problems
CE 598	Stream Restoration (Environmental River Mechanics)
CHE 465	Energy and the Environment
CHE 470	Safety, Health, and Loss Prevention
AB 320	Ecology and Environmental Biology

Advisor: Dr. Michael A. Robinson,
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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. practice their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment

2. continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods

3. function independently and in leadership positions in multidisciplinary teams

4. perform effectively within their profession, their community, and in the public service arena

CPE student outcomes

At the time of graduation, students will have demonstrated :

1. an ability to apply knowledge of mathematics, science, and engineering

2. an ability to design and conduct experiments, as well as to analyze and interpret data

3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

4. an ability to function on multidisciplinary teams

5. an ability to identify, formulate, and solve engineering problems

6. an understanding of professional and ethical responsibility

7. an ability to communicate effectively

8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

9. a recognition of the need for, and an ability to engage in life-long learning

10. a knowledge of contemporary issues

11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The computer engineering program is accredited by the Engineering Accreditation Commission of ABET,www.abet.org

COMPUTER ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
PH 111	Physics I	Credit 4	Fall Term		Credit
MA 111	Calculus I	5	MA 211	Differential Equations	4

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

CLSK 100	College & Life Skills	1	CSSE 232	Computer Architecture I	4
RH 131	Rhetoric and Composition	4	ECE 203	DC Circuits	4
	or		CHEM 111	General Chemistry I	4
HSS	Elective			Total	16
ECE 160	Engineering Practice	2	Winter Term		Credit
	Total	16	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
PH 112	Physics II	4	CSSE 332	Operating Systems	4
MA 112	Calculus II	5	ECE 204	AC Circuits	4
CSSE 120	Introduction to	4	HSS	Elective	4
	Software Development			Total	16
RH 131	Rhetoric and Composition	4	Spring Term		Credit
	or		MA 381	Introduction to Probability	4
HSS	Elective			with Applications	
	Total	17		to Statistics	
Spring Term		Credit	ECE 332	Computer Architecture II	4
PH 113	Physics III	4	ECE 205	Dynamical Systems	4
MA 113	Calculus III	5	HSS	Elective	4
ECE 130	Introduction to	4		Total	16
	Logic Design				
CSSE 220	Object-Oriented	4			
	Software Development				
	Total	17			

Junior

Year

Fall Term		Credit
MA 275	Discrete & Combinational	4
	Algebra I	
ECE 250	Electronic Device Modeling	4
ECE 300	Continuous-Time Signals	4
	Systems	
RH 330	Technical and Professional	4
	Communication	
	Total	16
Winter Term		Credit
ECE 380	Discrete-Time Signals Systems	4
ECE 331	Embedded System Design	4
ECE 351	Analog Electronics	4
	Math/Science Elective	4
	Total	16
Spring Term		Credit
ECE 333	Digital Systems	4
ECE 343	High Speed Digital Design	4
ECE 362	Principles of Design	3
HSS	Elective	4
	Total	15

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
	Total	15
Winter Term		Credit
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4

HSS	Elective	4
	Total	16
Spring Term		Credit
ECE 462	Engineering Design III	2
	Area Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
	Total	18
Total credits required:		194

AREA ELECTIVES

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

TECH ELECTIVE

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, geology or physics course as a math science elective except those courses that are cross-referenced with any engineering courses.

COMPUTER ENGINEERING CORE COURSES

SECOND MAJOR IN COMPUTER ENGINEERING

Course Number	Course Title	Credits	The ECE Department will not allow the following second major combinations:		
ECE130	Introduction to Logic Design	4	1. Degree in Electrical Engineering and a Second Major in Computer Engineering. 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.		
ECE160	Engineering Practice	2			
ECE203	DC Circuits	4			
ECE204	AC Circuits	4			
ECE205	Dynamical Systems	4			
ECE250	Electronic Device Modeling	4			
ECE300	Continuous-Time Signals Systems	4	Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.		
ECE331	Embedded System Design	4			
ECE332	Computer Architecture II	4			
ECE333	Digital Systems	4	Course Number	Course Title	Credits
ECE343	High Speed Digital Design	4	ECE130	Introduction to Logic Design	4
ECE351	Analog Electronics	4	ECE203	DC Circuits	4
ECE362	Principles of Design	3	ECE204	AC Circuits	4
ECE380	Discrete-Time Signals and Systems	4	ECE205	Dynamical Systems	4
ECE460	Engineering Design I	3	ECE250	Electronic Device Modeling	4
ECE461	Engineering Design II	4	ECE300	Continuous-Time Signals Systems	4
ECE462	Engineering Design III	2	ECE331	Embedded System Design	4
			ECE332	Computer Architecture II	4
			ECE333	Digital Systems	4
			ECE343	High Speed Digital Design	4
			ECE351	Analog Electronics	4
			ECE380	Discrete-Time Signals and Systems	4
			CSSE120	Introduction to Software Development	4

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits	Example Area Minor for Computer Science and Software Engineering		
ECE203	DC Circuits	4			
Required			Course Number	Course Title	Credits
ECE204	AC Circuits	4	ECE130	Introduction to logic	4
Required				Design	
ECE205	Dynamical Systems	4	ECE203	DC Circuits	4
ECE300	Continuous-Time Signals	4	Required		
	Systems		ECE204	AC Circuits	4
ECE380	Discrete-Time Signals and	4	Required		
	Systems		ECE250	Electronic Device	4
ECE310	Communication Systems	4		Modeling	
			ECE332	Computer Architecture II	4
			ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits	Optical Communications Certificate
ECE203	DC Circuits	4	Faculty advisors: B. Black and S. Granieri Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these
Required			
ECE204	AC Circuits	4	
Required			
ECE370	Power & Energy Systems	4	
ECE371	Sustainable Energy Systems	4	
ECE470	Power Systems I	4	
ECE471	Industrial Power Systems	4	

topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

- 1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
- 2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science

The Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The computer science curriculum is designed to prepare students for multiple careers in a rapidly changing environment. The department's courses emphasize fundamental concepts and techniques that will last longer than present technology.

Computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer architecture, programming languages, operating systems, and software engineering. Majors also complete important courses in closely related fields, e.g., discrete mathematics, digital logic design, and probability and statistics. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Courses in database systems, compilers, computer graphics, fractals and chaotic dynamical systems, artificial intelligence, theory of computation, analysis of algorithms, computer networks, computer vision, web-based information systems, and cryptography are available as advanced electives. A three-term senior project provides valuable practical experience in the specification, design, implementation, and documentation of large software systems. Qualified students can undertake independent study in advanced topics in computer science, participate in a research project with a faculty member, or complete a senior thesis.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

Computer science majors have diverse interests and career goals. Five free elective courses allow students to tailor their undergraduate education to their specific goals. Students planning to undertake graduate study in computer science usually take additional advanced courses in computer science, electrical engineering, and mathematics.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Computer science majors have unlimited access to the department's laboratories. Computer science majors are frequently employed by the computing center as user consultants, and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

Computer Science Program Educational Objectives

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Student Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering
13. Recognize the need for, and engage in, lifelong learning
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The computer science program is accredited by the Computing Accreditation Commission of ABET, www.abet.org

COMPUTER SCIENCE PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term		Credit	Year		
CSSE 120	Introduction to Software Development	4	Fall Term		Credit
PH 111	Physics I	4	CHEM 111	General Chemistry I	4
MA 111	Calculus I	5	CSSE 232	Computer Architecture I	4
CLSK 100	College & Life Skills	1	MA 212	Matrix Algebra and Systems of Differential Equations	4
RH 131	Rhetoric and Composition	4	MA 275	Discrete & Combinatorial Algebra I	4
	Total	18		Total	16
Winter Term		Credit	Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4	CSSE 230	Data Structures and Algorithm Analysis	4
PH 112	Physics II	4	CSSE 333	Database Systems	4
MA 112	Calculus II	5	MA 375	Discrete & Combinatorial Algebra II	4
HSS	Elective	4			
	Total	17			
Spring Term		Credit			

CSSE 132	Introduction to Computer Systems	4	HSS	Elective	4
				Total	16
MA 113	Calculus III	5	Spring Term		Credit
HSS	Elective	4	CSSE 304	Programming Lang. Con.	4
Science	Elective	4	ECE 332	Computer Architecture II	4
	Total	17	MA 381	Introduction to Probability with Applications to Statistics	4
			RH 330	Technical and Professional Communication	4
				Total	16
Junior Year					
Fall Term		Credit			
CSSE 371	Software Requirements Engineering	4			
CSSE/MA 473	Design and Analysis of Algorithms	4			
CSSE	Elective	4	Senior Year		
HSS	Elective	4	Fall Term		Credit
	Total	16	CSSE 487	Senior Research Project I or	4
Winter Term		Credit	CSSE 497	Senior Project I or	
CSSE 332	Operating Systems	4	CSSE 494	Senior Thesis I	
CSSE 374	Software Design	4	CSSE	Elective	4
CSSE/MA 474	Theory of Computation	4	HSS	Elective	4
HSS	Elective	4	Free	Elective	4
	Total	16		Total	16
Spring Term		Credit	Winter Term		Credit
CSSE	Elective	4	CSSE 488	Senior Research Project II or	4
	Technical Elective	4	CSSE 498	Senior Project II or	
Free	Elective	4	CSSE 495	Senior Thesis II	
Free	Elective	4	CSSE	Elective	4
	Total	16	HSS	Elective	4
				Technical Elective	4
				Total	14
			Spring Term		Credit
			CSSE 489	Senior Research Project III or	4
			CSSE 499	Senior Project III or	
			CSSE 496	Senior Thesis III	
			Free	Elective	4
			Free	Elective	4
				Total	12
			Total credits required:		192

CSSE electives cannot include any of CSSE 372, 373, 375, 376, and 477.

Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.

HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.
2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than

four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).

- 3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
- 4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
- 5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
- 6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 7. A total of 192 credits.

Area Minor in Computer Science

Advisor: Dr. Laxer

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

CSSE120 Introduction to Software Development
CSSE220 Object-Oriented Software Development
CSSE230 Data Structures and Algorithm Analysis
16 additional credits of computer science courses numbered above 200.
None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories

2. use economic theory to define, analyze and solve a wide range of problems.

3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.

4. communicate complex economics topics in both oral and written form.

5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	Credit 5	Fall Term		Credit
CLSK 100	College & Life Skills	1	MA 211	Differential Equations	4
RH 131	Rhetoric and Composition	4		Economics Elective	4
	or			*HSS Elective	4
HSS	Elective			Physical or Life Science	4
	Physical or Life Science	4		Total	16
	Total	14	Winter Term		Credit
Winter Term			MA 212		
MA 112	Calculus II	5		Matrix Algebra and Systems	4
CSSE 120	Introduction to	4		of Differential Equations	
	Software Development			Economics Elective	4
	Physical or Life Science	4		*HSS Elective	4
RH 131	Rhetoric and Composition	4		Physical or Life Science	4
	or			Total	16
HSS	Elective		Spring Term		Credit
	Total	17	MA 381	Introduction to Probability	4
				with Applications	
Spring Term			or	to Statistics	
MA 113	Calculus III	5			
SV 151	Principles of Economics	4	MA 223	Engineering Statistics	4

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

Physical or Life Science	4	Economics Elective	4
*HSS Elective	4	*HSS Elective	4
Total	17	Physical or Life Science	4
		Total	16

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

- 1. 20 credits of required Economics courses:
SV151 Principles of Economics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX496 Seminar for HSS Senior Projects
XX497 Directed Study for HSS Senior Project
- 2. 24 additional credits in Economics electives.
- 3. 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA211, 212 Differential Equations , and Matrix Algebra and Systems of Differential Equations
MA223 Engineering Statistics I or
MA381 Introduction to Probability
- 4. 12 additional credits in Mathematics other than MA351-356.
- 5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
- 6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
- 7. 4 credits in Engineering Management
- 8. 4 credits in Computer Science: CSSE 120
- 9. CLSK 100 (1 credit) and SV 200 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
SV 200	1
TOTAL	193



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

1. practice their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment

2. continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods

3. function independently and in leadership positions in multidisciplinary teams

4. perform effectively within their profession, their community, and in the public service arena

EE student outcomes

At the time of graduation, students will have demonstrated :

- an ability to apply knowledge of mathematics, science, and engineering

• an ability to design and conduct experiments, as well as to analyze and interpret data

• an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

• an ability to function on multidisciplinary teams

• an ability to identify, formulate, and solve engineering problems

• an understanding of professional and ethical responsibility

• an ability to communicate effectively

• the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

• a recognition of the need for, and an ability to engage in life-long learning

• a knowledge of contemporary issues

• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

ELECTRICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term		Credit	Year		Credit
PH 111	Physics I	4	Fall Term		
MA 111	Calculus I	5	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	CHEM 111	General Chemistry I	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

RH 131	Rhetoric and Composition	4	ECE 203	DC Circuits	4
	or		ECE 230	Introduction to	4
HSS	Elective			Microcontrollers	
ECE 160	Engineering Practice	2		Total	16
	Total	16	Winter Term		Credit
Winter Term		Credit	MA 212	Matrix Algebra and Systems	4
PH 112	Physics II	4		of Differential Equations	
MA 112	Calculus II	5		Math/Science Elective	4
ECE 130	Introduction to	4	ECE 204	AC Circuits	4
	Logic Design		HSS	Elective	4
RH 131	Rhetoric and Composition	4		Total	16
	or		Spring Term		Credit
HSS	Elective		MA 381	Introduction to Probability	4
	Total	17		with Applications	
Spring Term		Credit		to Statistics	
PH 113	Physics III	4	ECE 205	Dynamical Systems	4
MA 113	Calculus III	5	ECE 370	Power & Energy Systems	4
HSS	Elective	4		or	
CSSE 120	Introduction to	4	ECE 371	Sustainable Energy	
	Software Development			Systems	
	Total	17	HSS	Elective	4
				Total	16

Junior			Senior Year		
Year					
Fall Term		Credit	Fall Term		Credit
ECE 300	Continuous-Time Signals	4	ECE 460	Engineering Design I	3
	Systems			Tech Elective	4
ECE 250	Electronic Device Modeling	4		Area Elective	4
ECE 340	Electromagnetic Fields	4	HSS	Elective	4
RH 330	Technical and Professional	4		Total	15
	Communication		Winter Term		Credit
	Total	16	ECE 461	Engineering Design II	4
Winter Term		Credit		Tech Elective	4
ECE 380	Discrete-Time Signals	4		Area Elective	4
	and Systems		HSS	Elective	4
ECE 351	Analog Electronics	4		Total	16
ECE 341	Electromagnetic Waves	4	Spring Term		Credit
	Math/Science Elective	4	ECE 462	Engineering Design III	2
	Total	16		Area Elective	4
Spring		Credit	HSS	Elective	4
Term				Free Elective	4
ECE 310	Communications Systems	4		Free Elective	4
ECE 320	Linear Control Systems	4		Total	18
ECE 333	Digital Systems	4	Total credits required:		194
ECE 362	Principles of Design	3			
	Total	15			

AREA ELECTIVES

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

TECH ELECTIVE

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

ELECTRICAL ENGINEERING CORE COURSES

SECOND MAJOR IN COMPUTER ENGINEERING

Course Number	Course Title	Credits	
ECE130	Introduction to Logic Design	4	The ECE Department will not allow the following second major combinations:
ECE160	Engineering Practice	2	
ECE203	DC Circuits	4	1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
ECE204	AC Circuits	4	
ECE205	Dynamical Systems	4	2. Degree in Computer Engineering and a Second Major in Electrical Engineering.
ECE230	Introduction to Microcontrollers	4	
ECE250	Electronic Device Modeling	4	Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.
ECE300	Continuous-Time Signals and Systems	4	
ECE310	Communication Systems	4	EE Second Major
ECE320	Linear Control Systems	4	
ECE333	Digital Systems	4	Course Course Title Credits
ECE340	Electromagnetic Fields	4	
ECE341	Electromagnetic Waves	4	ECE130 Introduction to Logic Design 4
ECE351	Analog Electronics	4	ECE203 DC Circuits 4
ECE362	Principles of Design	3	ECE204 AC Circuits 4
ECE370 or ECE 371	Power & Energy Systems or Sustainable Energy Systems	3	ECE205 Dynamical Systems 4
ECE380	Discrete-Time Signals and Systems	4	ECE230 Introduction to Microcontrollers 4
ECE460	Engineering Design I	3	ECE250 Electronic Device Modeling 4
ECE461	Engineering Design II	4	ECE300 Continuous-Time Signals and Systems 4
ECE462	Engineering Design III	2	ECE310 Communication Systems 4
			ECE320 Linear Control Systems 4
			ECE333 Digital Systems 4
			ECE340 Electromagnetic Fields 4
			ECE341 Electromagnetic Waves 4
			ECE351 Analog Electronics 4
			ECE370 Power & Energy Systems 4
			or
			ECE371 Sustainable Energy Systems
			ECE380 Discrete-Time Signals and Systems 4
			MA381 Introduction to Probability with Applications to Statistics 4
			Total 64

AREA MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Example Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE130	Introduction to logic	4
Required				Design	
ECE204	AC Circuits	4	ECE203	DC Circuits	4
Required			Required		
ECE205	Dynamical Systems	4	ECE204	AC Circuits	4
ECE300	Continuous-Time Signals	4	Required		
	Systems		ECE250	Electronic Device	4
ECE380	Discrete-Time Signals and	4		Modeling	
	Systems		ECE332	Computer Architecture II	4
ECE310	Communication Systems	4	ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Areas of Concentration

Course Number	Course Title	Credits	
ECE203	DC Circuits	4	Concentration In Energy Production, Utilization, And Forecasting
Required			
ECE204	AC Circuits	4	Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics
Required			topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.
ECE370	Power & Energy Systems	4	
ECE371	Sustainable Energy	4	
	Systems		
ECE470	Power Systems I	4	
ECE471	Industrial Power Systems	4	

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

Enhanced Study in Communication Systems

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 410 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Continuous-Time Signals Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Dynamical Systems
- ECE300 Continuous-Time Signals Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

ENHANCED STUDY IN POWER SYSTEMS

Power Certificate

Take all of the following courses:

- ECE 571 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.

- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

EP Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will contribute to society locally, nationally or globally
- Our graduates will collaborate within their organization; and be active in research and development in a relevant area of science and technology.
- Our graduates will continue to develop professionally.

EP Student Learning Outcomes

- Outcome A:

Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
- Outcome B1:

Interpreting Data: Ability to interpret graphical, numerical, and textual data.
- Outcome B2:

System Level Modeling: Ability to model components and system level engineering problems.
- Outcome B3:

Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

- Outcome C: Design: Ability to design a product or process to satisfy client's needs subject to constraints.
- Outcome D: Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
- Outcome E: Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
- Outcome F: Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
- Outcome G: Communication: Ability to communicate effectively in oral, written and visual forms.
- Outcome H: Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Outcome I: Life Long Learning: A facility for independent learning and continued professional development.

ENGINEERING PHYSICS (Micro-Nano)

Freshman Year			Sophomore		
Fall Term		Credit	Year		Credit
PH 111	Physics I	4	Fall Term		
MA 111	Calculus I	5	ES 201	Conservation and	4
CLSK 100	College & Life Skills	1		Accounting Principles	
RH 131	Rhetoric and Composition	4	PH 235	Many Particle Physics	4
EM 104	Graphical Communications	2	MA 211	Differential Equations	4
	Total	16	PH 292	Physical Optics	4
Winter Term		Credit		Total	16
PH 112	Physics II	4	Winter Term		Credit
MA 112	Calculus II	5	EP 280	Intro to Nano Engineering	4
CHEM 111	General Chemistry I	4	PH 255	Foundations of	4
CSSE 120	Introduction to	4		Modern Physics	
	Software Development		MA 212	Matrix Algebra and Systems	4
ME 123	or			of Differential Equations	
	Computer Applications I		ES 202	Fluid & Thermal Systems	3
	Total	17		Total	15
Spring Term		Credit	Spring Term		Credit
PH 113	Physics III	4	HSS	Elective	4
MA 113	Calculus III	5	OE 295	Optical Systems	4
CHEM 113	General Chemistry II	4	SV 151	Principles of Economics	4
OE 172	Optics in Technology*	2	ES 203	Electrical Systems	4
EM 103	Introduction to Design**	2		Total	16
	Total	17*			
			Junior Year		
Fall Term		Credit			
PH 316	Electric and Magnetic Fields	4			
HSS	Elective	4			
PH 405	Semiconductor Materials	4			
	and Applications				
MA 223	Engineering Statistics I	4			
	Total	16			
Winter Term		Credit			
HSS	Elective	4			
PH 317	Electromagnetism	4			
RH 330	Technical and	4			
	Professional Communication.				
EP 406	Semiconductor Devices	4			
	and Fabrication				
	Total	16			
Spring Term		Credit			
EP 380	Nanotechnology,	4			
	Entrepreneurship and Ethics				
EP 410	Intro to MEMS	4			
EP 415	Engineering Physics	4			
	Project I				

	Engineering Elective	4
	or	
EP 408	Microsensors	
	Total	<u>16</u>

Senior Year

Fall Term		Credit
EP 416	Engineering Physics	4
	Project II	
EP 411	Advanced topics in MEMS	4
OE 495	Optical Metrology	4
	Engineering Elective	4
	Total	<u>16</u>
Winter Term		Credit
EP 417	Engineering Physics	4
	Project III	
HSS	Elective	4
	Elective	4
PH 401	Intro Quantum Mechanics	4
	Total	<u>16</u>
Spring Term		Credit
HSS	Elective	4
HSS	Elective	4
	Science Elective	4
	Engineering Elective	4
	or	
EP 408	Microsensors	
	Total	<u>16</u>
Total credits required:		193

*If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

EP 415, EP 416, and EP 417 are courses the student can take from any engineering department where the student has an area of concentration. The projects will have industrial clients that emphasize both physics and engineering and it may be jointly administered with the respective departments.

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

SUMMARY OF GRADUATION REQUIREMENTS FOR
ENGINEERING PHYSICS

Subjects	#Classes	Hours	
Physics(PH)	10	40	
Math(MA)	6	27	1. All the courses listed above by the number.
Chemistry(CHEM)	2	8	2. The program must be approved by the EP advisor.
Computer Science(CSSE)/ME	1/0 or 0/1	4	3. A list of the engineering electives is provided.
EM	2	4	4. An engineering elective is any RHIT course in an
CLSK	1	1	engineering discipline.
Engineering Science	3	11	5. Science electives are courses that should be taken in the
Optical Engineering (OE)	3	10	physics, chemistry, math, or biology programs.
HSS	9	36	6. A free electives is any course in engineering, science,
Engineering Physics (EP)	6	24	humanities, military science, or air science.
Engineering Physics Project(EP)	3	12	
Elective(Science, Eng. and Free)	4	16	
Total	50	193	
		Classes by Subjects	Hours
		Physics Coursework*	40
		Chemistry and Mathematics Coursework**	35
		Humanities and Social Science(Standard requirement)	36
		Computer Science, EM, CLSK Courses	9
		Engineering Science Classes	11
		Other Engineering Classes (Optical)	10
		EP Courses	24


EP Projects	12
Engineering Electives	8
Science and Free Electives	8
Total	193

Foundation Physics Classes

Foundation Physics Classes		General Foundation Classes	
Course Description	Hours	Course Description	Hours
PH 235 Many Particle Physics	4	PH 111 Physics I	4
PH 255 Foundations of Modern Physics	4	PH 112 Physics II	4
PH 316 Electric & Magnetic Fields	4	PH 113 Physics III	4
PH 317 Electromagnetism	4	MA 111 Calculus I	5
PH 401 Introduction to Quantum Mechanics	4	MA 112 Calculus II	5
Total	20	MA 113 Calculus III	5
		MA 211 Differential Equations	4
		MA 212 Matrix Algebra and Systems of Differential Equations	4
		MA 223 Engineering Statistics	4
		CHEM Engineering Chemistry I 105	4
		CHEM Engineering Chemistry II 107	4
		Total	47

Engineering Sciences Foundation

Engineering Sciences Foundation			Design Sequence	
Course	Description	Hours	Course Description	Hours
EM 104	Graphical Communications	2	EM 103 Introduction to Design	2
OE 172	Optics in Technology	2	EP 415 Engineering Physics Projects I	4
ES 201	Conservation and Accounting Principles	4	EP 416 Engineering Physics Projects II	4
ES 202	Fluids and Thermal Systems	3	EP 417 Engineering Physics Projects III	4
ES 203	Electrical Systems	4	Total	14
EP 280	Introduction to Nano-engineering	4	Recommended Engineering Electives: Requires the approval of the advisor.	
PH 292	Physical Optics	4	<u>The EP advisory committee can modify this list and add more courses over time.</u>	
OE 295	Optical Systems	4	ECE 204 AC Circuits	
EP 380	Nanotechnology, Entrepreneurship and Ethics	4	ECE 205 Dynamic Systems	
PH 405	Semiconductor Materials and Applications	4	ECE 351 Analog Electronics	
EP 406	Semiconductor Devices and Fabrication	4	ME 424 Composite Materials & Mechanics	
EP 410	Introduction to MEMS; Fabrication and Applications	4	OE 485 Electro-Optics & Applications	
EP 411	Advance Topics in MEMS	4	OE 450 Laser Systems	
OE 495	Optical Metrology	4	ME 328 Engineering of Materials	
	Engineering Elective	8	CHE 315 Materials Science & Engineering	
CSSE	Computer Programming	4	EP 440/407* Advanced Materials	
120/ME 123			* indicates a course that is under development.	
Total		67		

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Admissions

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News

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Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Mathematics

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

PROGRAM GOALS AND OBJECTIVES

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

DEGREE REQUIREMENTS

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core	12 hrs.
Three courses selected per the list below. Students completing the Continuous Applied	

Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- The project must involve work done by the student(s) to solve a problem presented by an external sponsor. The written project submission must be signed by the student's project advisor (who must be a member of the mathematics department) and two additional members (who are approved by the project advisor), and must be presented publicly to the department. The additional members of the committee may include

representatives of the sponsor.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team). The written submission must be signed by the student's thesis advisor (who must be a member of the mathematics department) and two additional faculty members (who are approved by the thesis advisor), and must be presented publicly to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.

Total hours required for graduation **195 hrs.**

* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
AB 101 — Essential Biology (or higher-level AB course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	
*** 200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.	24 hrs.
**** CLSK 100 — College and Life Skills	1 hr.
MA 200 Career Preparation	1 hr.

SUGGESTED SCHEDULE

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended basic chemistry course is CHEM 105 unless a student is taking a second major or minor requiring CHEM 111 or credit for CHEM 111 has already been received. If CHEM 111 is taken instead of CHEM 105 then the order of the basic science electives in the freshman and sophomore is the second science course listed. Two science courses are to be taken in the winter quarter of freshman year

MATHEMATICS

Freshman Year

Fall Term			Credit
MA	111	Calculus I	5
PH	111	Physics I	4
		or	
CHEM	111	General Chemistry I	4
RH	131	Rhetoric and Composition	
		or	4
HSS		Elective	
CLSK	100	College and Life Skills	1
CSSE	120	Introduction to Software Development	4
			16
			18

Winter Term			Credit
MA	112	Calculus II	5
PH	112	Physics II	4
		or	
PH	111	Physics I	4
CHEM	111	General Chemistry I	
		or	4
AB	101	Essential Biology (or higher level AB course)	
HSS		Elective	4
		or	
RH	131	Rhetoric Composition	4
			17

Spring Term			Credit
MA	113	Calculus III	5
PH	113	Physics III	4
		or	
PH	112	Physics II	4
MA	190	Contemporary Mathematics Problems	
HSS		Elective	4
			15

Junior Year

Fall Term			Credit
MA		Elective	4
		Technical Elective	4
		Technical Elective	4
HSS		Elective	4
		or	
RH	330	Technical and Professional Communication	4
			16

Sophomore Year

Fall Term			Credit
MA	211	Differential Equations	4
MA	275	Disc. & Comb. Algebra I	4
AB	101	Essential Biology (or higher level AB course)	4
		or	
PH	113	Physics III	4
*CSSE	220	Object-Oriented Software Development	
			16

Winter Term			Credit
MA	212	Matrix Algebra and Systems of Differential Equations	4
		Science Elective	4
		Technical Elective	4
HSS		Elective	4
**MA	200	Career Preparation	1
			17

Spring Term			Credit
MA	381	Introduction to Probability	4
MA	371	Linear Algebra I	4
		Technical Elective	4
HSS		Elective	4
			16

Senior Year

Fall Term			Credit
MA	491	Intro to Math Modeling (2 hours)	4
MA	492	Senior Project I (2 hours)	
		or	4
MA	496	Senior Thesis I (4 hours)	
		Free Elective	4
		Free Elective	4
HSS		HSS	4

Winter Term			Credit	16		
MA	366	Functions of a Real Variable	4			
MA		Elective	4	Winter Term		
		Technical Elective	4	Credit		
		Elective		MA	493	Senior Project II (2 hours)
HSS		or				or
			4			2
RH	330	Technical and Professional Communication		MA	497	Senior Thesis II (2 hours)
				MA		Elective
						4
						Free Elective
						4
			16			Free Elective
						4
Spring Term			Credit	18		
MA		Elective	4			
MA		Elective Technical Elective	4	Spring Term		
			4	Credit		
HSS		Elective		MA	494	Senior Project III (2 hours)
		or	4			or
						2
RH	330	Technical and Professional Communication		MA	498	Senior Thesis III (2 hours)
				MA		Elective
						4
						Free Elective
						4
			16			Free Elective
						4
				14		

Total credits required: 195

Notes:

- *MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework
- **MA 200 - Career Preparation - may be taken in either the winter or spring quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- Math Elective:** A course either required by the concentration or a true math elective.
- Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- Free Elective:** Any course.

Computational Science Major (CPLS) (Second Major Only)

Computational methods are widely employed in science and engineering for simulation, experimentation, analysis, and design. In many areas the use of high-performance computing is essential. The Computational Science major provides Rose-Hulman students with the opportunity to add to their primary major a second major that increases their knowledge and skill in applied scientific and engineering computation.

Requirements for a second major in Computational Science (71 credit hours)

The second major in Computational Science is open to all students. It requires 71 credit hours, including a 55

credit hour core and a 16 credit hour specialization. The courses used to satisfy the requirements in the Advanced Core may not be counted toward any other major or minor. All Computational Science programs of study are subject to approval by the Chair of the Computational Science Steering Committee

I. Computational Science Core (55 credit hours)

Fundamentals (35 credit hours)

- MA 111, 112, 113 Calculus I, II, III
- MA 211 Differential Equations
- MA 212 Matrix Algebra and Systems of Differential Equations
- CSSE 120 (1) Introduction to Software Development, or any of BE 100, CE 110, CHE 110 (plus 2 cr.), ME 123
- CSSE 132 or ECE130 Introduction to Computer Systems, Introduction to Logic Design
- MA 332 (2) Introduction to Computational Science, or any of CE 310 (plus 2 cr.) CHE 310, ME 323(plus 2 Credits)

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any upper-level computational science course (see list below)

List of Advanced Electives

- BE 510 Biomedical Signal and Image Processing
- CHE 521 Advanced Chemical Engineering Computation
- CSSE 304 Programming Language Concepts
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- ECE 582/PH 537 Advanced Image Processing
- EMGT 526 Technology Forecasting
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 348 Continuous Optimization
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis
- MA 435 Finite Difference Methods
- MA 439 Mathematical Methods of Image Processing
- MA 444 Deterministic Models in Operations Research
- MA 446 Combinatorial Optimization
- MA 490 Mathematical Biology
- ME 422 Finite Element Methods for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Elements Analysis
- Other courses may be counted as advanced electives upon approval by the Chair of Computational Science.

II. Area of Concentration (16 credit hours): Each student must complete 16 credit hours in an area of concentration within Computational Science. Courses used to satisfy the core requirements may not be used to satisfy the area of concentration requirements.

Computational Methods

- MA 371 or MA 373 Linear Algebra I, Applied Linear Algebra for Engineers
- MA 433 Numerical Analysis
- Eight credit hours chosen from CSSE 304, CSSE/MA 473, MA 348, MA 386, MA 434, MA 435, MA439, MA 444, MA 446, MA 485, ME 422

Computational Mechanics

- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications

- ME 401 Foundations of Fluid Mechanics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Element Analysis

Computational Signals and Image Processing

- ECE 380 Discrete-Time Signals and Systems
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- MA 439 Mathematical Methods of Image Processing

Computational Physics and Chemistry

- CHEM 361 Physical Chemistry I
- CHEM 362 Physical Chemistry II
- CHEM 363 Quantum Chemistry & Molecular Spectroscopy
- OE 570 Nanomedicine
- PH 540 Computer Physics

Computational Biomedics

- BE 482/MA 482 Bioengineering Statistics
- BE 535/OE 535 Biomedical Optics
- BE 541/ECE 597 Medical Imaging
- MA 490-01 Mathematical Biology 1
- MA 490-02 Mathematical Biology 2

AREA MINOR IN MATHEMATICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

AREA MINOR IN COMPUTATIONAL SCIENCE

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:

- MA332 Introduction to Computational Science
- MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The

department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the major.
- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

AREA MINOR IN STATISTICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- **Globally required mathematics courses**

MA 111 Calculus I
MA 112 Calculus II
MA 113 Calculus III
MA 212 Differential Equations

- **Required Introductory Statistics/Probability Courses**

MA 381 Introduction to Probability with Applications to Statistics,
One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is taken before MA223/MA382 the student will be strongly recommended to take MA382.

- **Required Second Statistics Course**

One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics

- **Electives**


3 courses (12 credits) selected from the following list, at least two of which must be starred. Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.

MA 385* Quality Methods
MA 386* Statistical Programming
MA 387* Statistical Methods in Six Sigma
MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers
MA 445 Stochastic Models in Operations Research
MA 481* Mathematical Statistics
MA 485* Regression and Time Series Analysis
MA 487* Design of Experiments
MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students
- Only MA111, MA112, MA113, MA212 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.

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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Mechanical Engineering

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Since mechanical engineering is a broad field of endeavor, the curriculum offers a strong technical elective program to allow each student to craft a broad educational experience and to develop the flexibility to pursue diverse career goals.

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Design Processes and Methodology.

The strength of any department is its faculty. The mechanical engineering faculty is committed to providing a dynamic and innovative learning environment and to maintaining and increasing their technical competence in a rapidly changing world. Stereotypes notwithstanding, they understand that people are more important than things. Thus, they encourage each student to seek them out when he or she has academic problems or needs guidance in career planning.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 20 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

Vision: To graduate the best baccalaureate mechanical engineers.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

- a. *an ability to apply knowledge of mathematics, science, and engineering*
- b. *an ability to design and conduct experiments, as well as to analyze and interpret data*
 1. *Identify the problem and develop an appropriate experimental approach*
 2. *Select measurement techniques to collect appropriate data and justify that selection.*
 3. *Estimate experimental uncertainties.*
 4. *Collect and present data in an accurate and orderly way.*
 5. *Use appropriate statistical procedures to analyze and evaluate the information contained in a data set.*
 6. *Analyze the data and draw supportable conclusions from the result*
- c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
 1. *Understand the problem.*
 2. *Develop a design specification that addresses customer/client needs and constraints.*
 3. *Carry out a conceptual design by generating multiple solutions that address the requirements of the design specification.*
 4. *Evaluate the feasibility of the solutions.*
 5. *Choose an appropriate solution and justify that solution*
 6. *Carry out a conceptual-level design using appropriate design tools and methodologies.*
 7. *Test and refine the implementation until the product or process design specifications are met or exceeded.*
 8. *Document the finished product or process as appropriate for the discipline according to standard practice.*
- d. *an ability to function on multi-disciplinary teams*
 1. *Demonstrate how you reached a decision as a team.*
 2. *Describe the team role you filled and how that contributed to the final project.*
 3. *Listen openly, actively, and critically.*
- e. *an ability to identify, formulate, and solve engineering problems*
 1. *Inspect and define the problem.*
 2. *Identify the basic principles and concepts that apply to the situation.*
 3. *Build appropriate model(s).*
 4. *Solve the problem by choosing appropriate tools (analytical, experimental, and computational).*
 5. *Check a solution using appropriate criteria.*
- f. *an understanding of professional and ethical responsibility*
 1. *Explain important ethical obligations associated with your discipline.*
 2. *Apply a systematic ethical framework to an ethical issue or situation in a disciplinary context.*
- g. *an ability to communicate effectively*
 1. *Provide a substantive critique that includes recommendations for improvements.*
 2. *Adapt technical information for a non-specialized audience.*
 3. *Convey information effectively through visual media.*
 4. *Present information visually using drawings, graphs and sketches.*
 5. *Deliver oral presentations with clarity and professionalism.*

- h. *the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
 - 1. *Engage in the arts (music, theater, art, dance, creative writing, etc.)*
 - 2. *Analyze patterns, dynamics, or values of human interaction in social or cultural systems.*
 - 3. *Analyze beliefs, backgrounds, cultures, or societies different from your own.*
 - 4. *Interpret cultural artifacts and/or ideas in philosophy, the arts, or the sciences.*
- i. *a recognition of the need for, and an ability to engage in life-long learning*
 - 1. *Students will describe how their current state of performance in an ability has already impacted or might in the future negatively impact their project or team.*
 - 2. *Students will describe steps they will follow to reach their desired performance level in the ability.*
 - 3. *Students will describe evidence that indicates that they have achieved their professional development goal.*
 - 4. *Students will describe the "most significant" professional development they achieved and explain its impacts.*
 - 5. *Students will explain what they have learned about the professional development process that will transfer into life after graduation.*
- j. *a knowledge of contemporary issues*
 - 1. *Students will identify the problem.*
 - 2. *Students will describe the problem from different perspectives (At least two sides)*
 - 3. *Students will identify stakeholders and describe how stakeholders are affected*
 - 4. *Students will justify arguments logically.*
 - 5. *Students will reference sources appropriately.*
- k. *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

Area Minor* in Thermal-Fluids**

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

ME 301 Thermodynamics II
CHE 303 Chem. Engineering Thermodynamics
ME 302 Heat Transfer
CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems

ME 407 Power Plants**
ME 408 Renewable Energy
ME 409 Air Conditioning*
ME 410 Internal Combustion Engines
ME 411 Propulsion Systems**
ME 426 Turbomachinery

Thermal Fluid Sciences

ME 401 Foundation of Fluid Mechanics
ME 402 Advanced Heat Transfer*
ME 405 Theoretical Aerodynamics

- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics**
- ME 502 Topics in Heat Transfer*
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

**Requires one of the thermodynamics prerequisites from section 2 above.
* Requires one of the heat transfer prerequisites from section 2 above.
*** ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may include special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

- ECE/ME 497 Introduction to Model-Based System Design
- ECE/ME 497 Advanced Model Based-System Design

Elective Courses

- CHEM 470 Combustion Chemistry

- ECE 320 Linear Control Systems
or
ME 406 Control Systems

- ECE 420 Nonlinear Control Systems
or
ME 506 Advanced Control Systems

- ECE 370 Machines & Power
- ECE 410 Communication Networks
- ECE 452 Power Electronics

- ME 408 Renewable Energy
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 422 Finite Elements for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 450 Combustion

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

MA 336 Boundary Value Problems

ME 405 Theoretical Aerodynamics

ME 401 Foundation of Fluid Mechanics

ME 411 Propulsion Systems

ME 422 Intro to Finite Element Fundamentals

ME 426 Turbomachinery

ME 427 Introduction to Computational Fluid Dynamics

ME 461 Aerospace Design

ME 503 Viscous Flow

ME 510 Gas Dynamics

ME 512 Light Weight Structures

ME 522 Advanced Finite Element Analysis

PH 322 Celestial Mechanics

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

CE 561 or CHE 450 Air Pollution (cross-listed class)

CE 590 Climate Change Assessment

CHE 490 Energy and Environment

CHE 512 Petrochemical Processes

ECE 370 Power and Energy Systems

ECE 371 Industrial Power Systems

ME 407 Power Plants

ME 408 Renewable Energy

ME 450 Combustion

ME 501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma

Engineering Management List

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 520 Accounting for Technical Managers
- EMGT 521 Financial Management in a Technical Environment
- EMGT 522 Organizational Management
- EMGT 523 Marketing Issues in a Technical Environment 4
- EMGT 524 Production/Operations Management
- EMGT 526 Technology Management and Forecasting
- EMGT 527 Project Management
- EMGT 531 Economics for Technical Managers
- EMGT 532 Technical Entrepreneurship
- EMGT 533 Intercultural Communication
- EMGT 534 Management Science
- EMGT 535 Strategies for Organizational Change
- EMGT 586 Supply Chain Management
- EMGT 587 Systems Engineering
- EMGT 588 Quality Management I
- EMGT 589 Manufacturing Systems

Humanities, Social Sciences List

- GS 350 International Trade
- GS 351 International Finance
- IA 230 Fundamentals of Public Speaking
- SV 151 Principles of Economics
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- IA 352 Game Theory
- SV 303 Business and Engineering Ethics
- SV 304 Bioethics
- SV 352 Money & Banking
- SV 353 Industrial Organization
- SV 354 Environmental Economics
- SV 356 Corporate Finance
- EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 588 Quality Management
- EMGT 589 Manufacturing Systems
- MA 385 Quality Methods
- ME 317 Design for Manufacturing
- ME 417 Advanced Materials Engineering
- ME 435 Robotics
- ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics
- ME 502 Topics in Heat Transfer

ME 503 Viscous Fluid Flow
ME 510 Gas Dynamics
EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the ****Thermal Fluid Systems**** list and at least two courses are taken from the ****Thermal Fluid Sciences**** list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org


MECHANICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
		Credit			Credit
MA 111	Calculus I	5	MA 211	Differential Equations	4
PH 111	Physics I	4	ES 201	Conservation &	4
CLSK 100	College & Life Skills	1		Accounting Principles	
EM 104	Graphical Communications	2	ES 203	Electrical Systems	4
RH 131	Rhetoric and Composition	4	HSS	Elective	4
	split fall or winter with			Total	16
HSS	Elective				
	Total	16			
Winter Term			Winter Term		
		Credit			Credit
MA 112	Calculus II	5	MA 212	Matrix Algebra and	4
PH 112	Physics II	4		Systems	
ME 123	Computer Applications I	4		of Differential Equations	
RH 131	Rhetoric and Composition	4	ES 202	Fluid & Thermal Systems	3
	split fall or winter with		ES 204	Mechanical Systems	3
HSS	Elective		CHEM 111	General Chemistry I	4
	Total	17	HSS	Elective	4
				Total	18
Spring Term			Spring Term		
		Credit			Credit
MA 113	Calculus III	5	MA 223	Statistics for Engineers	4
PH 113	Physics III	4	ES 205	Analysis & Design of	4
EM 103	Introduction to Design	2		Engineering Systems	
EM 121	Statics and Mechanics	4	CHEM 113	General Chemistry II	4
	of Materials I		HSS	Elective	4
	Total	15		Total	16
Junior			Senior Year		
Year			Fall Term		
		Credit			Credit
ME 301	Thermodynamics II	4	ME 430	Mechatronic Systems	4
EM 204	Statics and Mechanics	4		split fall or winter with	
	of Materials II		ME 421	M.E. Lab and *Tech Elective	(2+4)
*Tech	Elective	4	ME 406	Control Systems	4
*Free	Elective	4		or	
	Total	16	EM 406	Vibration Analysis	(4)
			ME 480	Machine Component Design	4
				split Jr. spring or Sr. fall with	
			ME 470	Engineering Design Proc & Method(3)	
			*Tech	Elective	(4) 4
				Total	(17) or 16
Winter Term			Winter Term		
		Credit			Credit
ME 317	Design for Manufacturing	(3) 3	ME 471	Capstone Design I	(3) 3
ME 321	Measurement Systems	4	ME 421	M.E. Lab and *Tech Elective	2+4
	split winter or spring with				
ME 323	Computer Applications II	(2)			
Science	Elective	(4)			

ME 328	Materials Engineering	(4)	4	split fall or winter with	
RH 330	Technical Communications	(4)		ME 430 Mechatronic Systems	(4)
	split winter or spring with			HSS Elective	(4) 4
HSS	Elective		4	*Free Elective	(4) 4
	Total	(17) or		Total	(15) or 17
		15		Spring Term	Credit
ME 302	Heat Transfer	(4)	4	ME 472 Capstone Design II	3
ME 323	Computer Applications II		2	*Tech Elective	4
Science	Elective		4	*Tech Elective	4
	split winter or spring with			HSS Elective	4
ME 321	Measurement Systems	(4)		Total	15
ME 470	Engineering Design Proc & Method		3	Total credits required:	194
ME 480	split Jr. spring or Sr. fall with	(4)			
	Machine Component Design				
HSS	Elective	(4)			
	split winter or spring with				
RH 330	Technical Communications		4		
	Total	(16) or			
		17			

*28 credit hours. in electives composed of 20 cr. hrs. in technical electives and 8 cr. hrs. in free electives.

*A **technical elective** is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A **science elective** is any course in applied biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.

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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>

OE Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will make a meaningful impact on society.
- Our graduates will behave ethically and act as responsible members of the engineering and science community.
- Our graduates will continue to develop professionally

OE Student Learning Outcomes

Outcome A: Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Outcome B1:	Interpreting Data: Ability to interpret graphical, numerical, and textual data
Outcome B2:	System Level Modeling: Ability to model components and system optical engineering problems
Outcome B3:	Experimentation:Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before
Outcome C:	Design: Ability to design a product or process to satisfy client's needs subject to constraints
Outcome D:	Team work: Ability to work in multi-disciplinary teams and understand the effective team dynamics and be able to deliver a product
Outcome E:	Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world optical engineering problems
Outcome F:	Professional Practice and Ethics: A sound understanding what an optics professional is and have an awareness and understanding of professional ethics
Outcome G:	Communication: Ability to communicate effectively in oral, written and visual forms
Outcome H:	Contemporary issues and global awareness: An awareness of contemporary issues in engineering profession and the role of professionals in an interdependent global society
Outcome I:	Life Long Learning: A facility for independent learning and continued professional development

The optical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

OPTICAL ENGINEERING

Freshman Year

Fall Term				Credit
MA	111	Calculus I		5
PH	111	Physics I		4
CLSK	100	College and Life Skills		1
RH	131	Rhetoric and Composition		4
EM	104	Graph Comm		2
				16

Winter Term				Credit
PH	112	Physics II		4
MA	112	Calculus II		5
CHEM	111	General Chemistry I		4
ME	123	Computer Applications I		4
				17

Spring Term				Credit
PH	113	Physics III		4
MA	113	Calculus III		5
CHEM	113	General Chemistry II		4
OE	172	Optics in Tech		2
EM	103	Intro Eng. Design		2
				17

Junior Year

Fall Term				Credit
PH	316	Elec & Mag Fields		4
OE	360	Optical Materials and		4

Sophomore Year

Fall Term				Credit
MA	223	Engineering Statistics		4
SV	151	Principles of Economics		4
PH	235	Many-Part Physics		4
MA	211	Differential Equations		4
PH	292	Physical Optics		4
				16

Winter Term				Credit
ECE	203	DC Circuits		4
PH	255	Fnd. of Mod. Phys.		4
MA	212	Differential Equations		4
OE	280	Paraxial Optics		4
				16

Spring Term				Credit
		Free Elective		4
OE	295	Optical Systems		4
SV	151	Principles of Economics		4
MA	223	Engineering Statistics		4
ECE	204	AC Circuits		4
				16

Senior Year

Fall Term				Credit
OE	480	Lens Des & Abb		4
OE	495	Optical Metrology		4

		Opto-Mechanics		HSS		Elective	4
PH	405	S.C. Mat & Appl.	4	OE	416	Opt Eng Des II	4
ECE	205	Dynamical Systems	4				
							16
			16				
Winter Term				Winter Term			Credit
			Credit				
				OE	485	Electro-Opt. & App.	4
OE	393	Fiber Opt & App	4	HSS		Elective	4
		Free Elective	4			Engineering Elective	4
EP	406	SC Dev & Fab	4	OE	417	Opt Eng Des III	4
HSS		Elective					
		or	4				
RH	330	Technical and Professional Communication					16
				Spring Term			Credit
			16				
Spring Term			Credit			Engineering Elective	4
				HSS		Elective	4
				HSS		Elective	4
						Free Elective	4
OE	415	Opt Eng Des I	4				
HSS		Elective	4				
HSS		Elective					16
		or	4				
RH	330	Technical and Professional Communication					
				Total credits required: 194			
OE	450	Laser Systems	4				
			16				

If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

SUMMARY OF GRADUATION REQUIREMENTS FOR OPTICAL ENGINEERING

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects	Hours
Optics Coursework	46
Physics Coursework	20
Freshmen Physics, Chemistry and Mathematics Coursework	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous	25
Total	194

Physics Classes		Hours
Course	Description	
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4
PH292	Physical Optics	4

PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM105	Engineering Chemistry I	4
CHEM107	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
EP 406	Semiconductor Devices and Fabrication	4
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
Total		25

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required Courses

Course	Hours	Course Description
OE 280	4	Paraxial Optics
PH 292	4	Physical Optics
OE 295	4	Optical Systems

Plus at least two courses from one of the areas listed below:

Lens Design Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 480	4	Lens Design and Aberrations
OE 490	4	Directed Research (4 Credits Only)
Photonics/Electro-optics Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-optics and Applications
OE 490	4	Directed Research (4 credits only)
OE 493	4	Fundamentals of Optical Fiber Communications
Image Processing Area		
Course	Hours	Course Description
OE 415	4	Optical Engineering Design I
OE 490	4	Directed Research (4 Credits Only)
PH 437/ECE 480	4	Introduction to Image Processing
PH 537/ECE 582	4	Advanced Image Processing

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)
Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203	4	DC Circuits
ECE 204	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs

currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

ECE 310 Communication Systems
OE 393 Fiber Optics and Applications
OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

ECE 380 Discrete Time & Continuous Systems
ECE 410 Communication Networks
ECE 414 Wireless Systems
OE 360 Optical Materials and Opto-mechanics
OE 435 Biomedical Optics
OE 450 Laser Systems and Applications
OE 485 Electro-Optics and Applications



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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

PHYSICS

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
MA	111	Calculus I	5			Free Elective†	4
PH	111	Physics I	4	PH	235	Many Particle Physics	4
CLSK	100	College and Life Skills	1	MA	211	Differential Equations	4
RH	131	Rhetoric and Composition		PH	292	Physical Optics	4
		or	4				
HSS		Elective					16
EM	104	Graphical Communications	2				
			16				
Winter Term				Winter Term			
			Credit				Credit
PH	112	Physics II	4	PH	255	Fund. of Modern Physics	4
MA	112	Calculus II	5			Elective	4
CHEM	111	General Chemistry I	4	HSS		Technical Elective	4
		Computing Elective*	2-4	MA	212	Matrix Algebra and Systems of	4
						Differential Equations	4
							16

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

- Additional Programs of Study
- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

15 or 17				Spring Term			Credit
Spring Term							
Credit							
PH	113	Physics III	4	PH	314	Theoretical Mechanics I	4
MA	113	Calculus III	5	HSS		Elective	4
CHEM	113	General Chemistry II	4	MA	371	Linear Algebra I	4
HSS		Elective				Math Elective†	4
		or	4				
RH	131	Rhetoric and Composition					16
17							
Junior Year				Senior Year			
Fall Term				Fall Term			
Credit				Credit			
HSS		Elective	4	Math		Elective†	4
PH	316	Electric and Magnetic Fields	4			Technical Elective†	4
		Technical Elective†	4	HSS		Elective	4
PH	405	Semiconductor Materials and Applications	4			Free Elective	4
16				16			
Winter Term				Winter Term			
Credit				Credit			
PH	317	Electromagnetism	4	PH	425	Advanced Physics Lab II	4
PH	401	Intro Quantum Mechanics	4	HSS		Elective	4
HSS		Elective	4			Technical Elective†	4
		Physics Elective†	4			Free Elective†	4
16				16			
Spring Term				Spring Term			
Credit				Credit			
PH	325	Advanced Physics Lab I	4	OE	450	Technical Elective†	4
HSS		Elective	4			Laser Sys & App	
OE	450	Laser Sys & App				or	4
		or	4			Physics Elective	
		Physics Elective†				Free Elective	4
PH	327	Thermodynamics & Statistical Mechanics	4			Physics Elective†	4
16				16			
16							
Total credits required: 192							

Total credits required: 192

* Computing elective: 2 or 4 credit course on computing from the following course: AB 140, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

SUMMARY OF GRADUATION REQUIREMENTS FOR PHYSICS MAJORS

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
- 4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses

- (cannot include ECE340).
5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
6. Sixteen credits of free electives (cannot include ECE340).
7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
8. A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.
9. A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
PH 215	Introduction to Chaos	2
PH 231	Intro to Astronomy and Astrophysics	4
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 322	Celestial Mechanics and Solar	4
PH 330	Material Failure	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
PH 407	Solid State Physics	4
PH 437	Introduction to Image Processing	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	Arranged
PH 470	Directed Research	Arranged
PH 480	Seminar	Arranged
PH 490	Directed Research	Arranged
PH 497+	Senior Thesis	Arranged
PH 498+	Senior Thesis	Arranged
PH 499+	Senior Thesis	Arranged
PH 512	Methods of Mathematical Physics	4
PH 514	Quantum Mechanics	4
PH 530	Advanced Acoustics	4
PH 537	Advanced Image Processing	4
PH 538	Introduction to Neural Networks	4

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year for a total number of 8 credit hours over the three quarter sequence. Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

****Math and Chemistry Courses:**

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	
	Linear Algebra	4
MA 371	General Chemistry I	4
CHEM 111	General Chemistry II	4
CHEM 113		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

Area Minor Programs

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus 12 credit hours from the following courses:

Course	Course Title	Hours
PH 270/470	Special Topics in Physics †	ARR
PH 290/490	Directed Research †	ARR

PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4
PH 460	Directed Study †	ARR

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 290/490	Directed Research	2

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4

ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4
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Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4
PH 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
PH 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

The software engineering program prepares its graduates for many types of careers in the computing industry as well as for graduate study in software engineering and in closely related disciplines. Within a few years after completing the software engineering degree program, our graduates will:

- Advance beyond their entry-level position to more responsible roles, or progress towards completion of advanced degree(s).
- Continue to keep pace with advancements in their disciplines, and develop professionally in response to changes in roles and responsibilities.
- Demonstrate that they can collaborate professionally within or outside of their disciplines at local, regional, national, or international levels.
- Contribute to the body of computing products, services, or knowledge.

Software Engineering Student Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The software engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

SOFTWARE ENGINEERING

Freshman Year

Fall Term				Credit
CSSE	120	Intro to Software Development	4	
MA	111	Calculus I		
PH	111	Physics I	5	
RH	131	Rhetoric & Composition	4	
CLSK	100	College and Life Skills	4	
			1	
				18

Sophomore Year

Fall Term				Credit
CHEM	111	General Chemistry I		4
CSSE	232	Computer Architecture I		4
MA	212	Matrix Alg & Syst of Differtl		4
MA	275	Equa		4
		Discrete & Combinatorial		
		Algebra I		
				16

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE477, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA212, MA275, MA375, MA381; PH111, PH112, CHEM111; RH 131, RH330; CLSK100.
2. One additional CSSE elective course except CSSE 325, CSSE 473, CSSE 474, and CSSE 479. In

addition, use of CSSE 49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.

- 3. A Domain Track set of courses. All of the courses for each of the [Domain Tracks](#) is listed on the CSSE website. That site also explains the procedures and deadlines by which a student must declare their Domain Track.
- 4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
- 5. Four credits of science electives, which can be any CHEM, GEOL, PH, or AB courses not already required for the software engineering major.
- 6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
- 7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

CSSE 120, *Introduction to Software Development*
CSSE 220, *Object-Oriented Software Development*
CSSE 230, *Data Structures and Algorithm Analysis*
CSSE 371, *Software Requirements Engineering*
CSSE 374, *Software Design*

Two additional courses in software engineering chosen from CSSE 372, 373, 375, 376, and 477.



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation-contact Air Force ROTC for more details.

SCHOLARSHIPS

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

Profession of Arms Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.

Communications Skills Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

General Military Courses

Freshman Year			Credit	Sophomore			Credit
AS 101	Found. of the US Air Force I		1	Year			
AS 101L	Leadership Laboratory		0	AS 201	Evol. of Air & Space Power I		2
AS 102	Found. of the US Air Force II		1	AS 201L	Leadership Laboratory		0
AS 102L	Leadership Laboratory		0	AS 202	Evol. of Air & Space Power		2
AS 103	Found. of the US Air Force III		1		II		
AS 103L	Leadership Laboratory		0	AS 202L	Leadership Laboratory		0
				AS 203	Evol. of Air & Space Power		2
					III		
				AS 203L	Leadership Laboratory		0


Professional Officer Courses

Junior Year			Credit	Senior			Credit
AS 301	Air Force Lead. Studies I		4	Year			
AS 301L	Leadership Laboratory		0	AS 401	Nat.Sec.Aff./Prep. for Active Duty		4
AS 302	Air Force Lead. StudiesII		4		I		
AS 302L	Leadership Laboratory		0	AS 401L	Leadership Laboratory		0
AS 303	Air Force Lead. Studies III		4	AS 402	Nat.Sec.Aff./Prep. for Active Duty		4
AS 303L	Leadership Laboratory		0		II		
				AS 402L	Leadership Laboratory		0
				AS 403	Nat.Sec.Aff./Prep. for Active Duty		4
					III		
				AS 403L	Leadership Laboratory		0

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.



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Institute of Technology

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Terre Haute, IN 47803
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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Humanities and Social Sciences

AREAS OF STUDY

Global Studies

Ideas and Art

Society and Values

Modern Languages

MAJORS

Economics

International Studies (second major only)

GERMAN TECHNICAL TRANSLATION CERTIFICATE

MINORS

Anthropology

Art

East Asian Studies

Economics

European Studies

Geography

German

History

Japanese

Language and Literature

Latin American Studies

Music

Political Science

Philosophy and Religion

Psychology

Spanish

Professors Bremmer, Carlson, Carvill, Casey, Chapman, Christ, Clark, Dyer, Garcia, Gardner, Hartner, Heeter, Hirotani, House, Jern, Kim, Kukral, Letsinger, Li, Livingston, Martland, Michel, Minster, Smith, C. Taylor, Watt, and Williams.

MISSION STATEMENT

To enable our students to become creative, sophisticated thinkers, active citizens, and effective leaders in the global community, the department contributes to a broad liberal education, introducing students to a wide array of disciplines and traditions in the humanities and social sciences. In doing so, it provides learning experiences that, in addition to their intrinsic value, enrich a scientific and technical education.

Educational Objectives

Within the context of a liberal education, the department fosters in its students the desire and the ability to:

think critically

, forming cogent, informed opinions, defining and solving problems with an awareness that societal processes are complex and interactive;

communicate effectively

to diverse audiences, including those from other cultures and communities;

succeed in a global context

by understanding and adapting to diverse cultures, alternative points of view, and the challenges of globalization;

exhibit ethical and responsible leadership

as individuals, citizens, and professionals, committed to lifelong learning and achievement.

Disciplines

The HUMANITIES study what it means to be human within a contemporary or historical context. These disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

https://www.rose-hulman.edu/course-catalog/course-catalog-2013-2014/course-descriptions/humanities-and-social-sciences.aspx#intl-studies[1/20/2017 12:41:01 PM]

quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art	Anthropology
English and Literature	Economics
Foreign Languages(German, Japanese, and Spanish)	Geography
History	Political Science
Music	Psychology
Philosophy and Religion	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- **Global Studies (GS prefix):** Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- **Ideas and Arts (IA prefix):** Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.
- **Society and Values (SV prefix):** Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communication are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communication is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general **lower level courses (100 and 200 level)** tend to be broad surveys of particular subject areas within disciplines. **Upper level courses (300 and 400 level)** are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General

- All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

- All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted free elective transfer credit, but are not exempted from RH 131.
- **EXEMPTION:** An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. Any HSS course may be substituted for RH 131 for exempted students.
 1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.
 2. Has received grades of B or higher in all high school English courses.

- **INTERNATIONAL STUDENTS:** International students for whom English is not their native language will be required to take an assessment test to gauge their written, oral, and listening proficiency in English. The purpose of this testing is to ensure that all students have the proper communication skills to advance successfully through the challenging Rose-Hulman curriculum. Based on this assessment, some students will be required to take CLSK121 College English. Those students must successfully complete CLSK121 prior to taking RH131 Rhetoric and Composition.

3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.
 1. A minimum of two terms of the same language (or the equivalent thereof) must be completed in order to apply foreign language credits toward Humanities and Social Sciences requirements. If only SP111, JP111 or GE111 is completed, that course will not be allowed to satisfy an HSS requirement."
 2. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.
 3. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three thematic categories as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each thematic category in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
 4. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
 5. Students may not earn foreign language credit in their native languages.
 6. Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. Minors

- Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

HELP WITH REQUIREMENTS

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, or Spanish, by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the

appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

<i>Minor</i>	<i>Adviser</i>
Anthropology	Scott Clark
Art	Steve Letsinger
East Asian Studies	Scott Clark
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter
Geography	Michael A. Kukral
History	Samuel Martland
Japanese	Maki Hirotani
Language and Literature	Caroline Carvill
Music	David Chapman
Latin American Studies	Gustavo Garcia
Philosophy and Religion	Dan Hartner
Political Science	Terrence Casey
Psychology	Alan Jern
Spanish	John Gardner

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Introduction to East Asian History 4R-OL-4C

Examine the changing political-economic and cultural orders in the East Asian region (including China, Japan, and Korea) from imperial to modern era.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Asian Religions and Philosophy 4R-OL-4C

Focuses on the thought systems of India, China, and Japan. Discusses Hinduism, Buddhism, Confucianism, Taoism, and Shinto.

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History 4R-OL-4C

Explores the history and interaction of major world regions, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction's humanistic usefulness in examining human values from an "extra-

species, extra-terrestrial" perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 285 Humans and Culture 4R-OL-4C

Examines human adaptation and diversity; language and its use; the development and variety of economic, political, religious, family gender and expressive institutions.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS 330 Contemporary Global Film 3R-3L-4C

Examines films outside of the Hollywood tradition with a consideration of the cultural, political, and economic influences that shape film.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 350 International Trade and Globalization 4R-OL-4C Prereq: SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Prereq: SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Prereq: SV 151

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 363 European Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of selected European political systems.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Contemporary Japan (Field trip to Japan) 4R-OL-4C

Examine contemporary Japan through the lectures, reading, and discussions during the course. Explorer the culture through the field trip to Japan.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 384 Japanese Society 4R-OL-4C

Examines the context within which individual Japanese live and work in contemporary Japanese society. Considers the “traditional” roots of Japan, the impact of industrialization, and current trends. Emphasizes the change and continuity in Japanese life, including the family and marriage, rural and urban lifestyles, education, and the organization of management and labor.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS 425 Cities and Technology in the Industrial Age 4R-OL-4C

Explores development of cities and the machines and systems that make them possible as human life became more and more urban and industrial from 1700 to the present. Compares urban growth and city life in different parts of the world.

GS 430 World Drama 4R-OL-4C

Examines drama from multiple cultures and time periods through a thematic lens.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS 470 Japanese Media 4R-OL-4C

Explores historical and contemporary media-related Japanese culture, both in visual and text communications.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

IDEAS AND ARTS -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R-OL-4C

Introduces the student to the methods and subject matter of philosophy through a selective consideration of fundamental philosophical problems such as the nature of reality, the existence of God, the criteria of knowing, and the basis of morality.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Jane Austen and the Rhetoric of Fiction 4R-OL-4C

Provides a guide to reading, appreciating, and analyzing Jane Austen's major novels. Analyzes a variety of film adaptations, comparing them to the novels in their rhetorical effects.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 3R-3L-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Concepts 4R-OL-4C

Teaches basic techniques of music notation and analysis of melody, harmony, rhythm, form, and style. Includes a comprehensive Analysis Project.

IA 302 Philosophy of Religion 4R-OL-4C

Examines the basic philosophical problems found in religion. Deals specifically with the nature of religion, the nature and existence of God, religious language, and the religious life.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 330 Documentary Film 3R-3L-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 338 Medicine in Literature 4R-OL-4C

Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 340 Ethics in Human Communication 4R-OL-4C

Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of

advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 346 Music Theory II: Applications 4R-OL-4C Prereq: IA246 or consent of instructor

Applies notational and analytical techniques to arranging/composing tasks, using music notation software.

IA 348 Music Performance 1R-OL-1R Prereq: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C Prereq: SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C Prereq: SV 151

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Prereq: SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C Prereq: SV 151

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Prereq: SV 151

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Prereq: SV 151

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

IA 471 Literature of Madness 4R-OL-4C

Analyzes the literary, biographical, and scientific relationships between artistic and manic-depressed temperaments. Examines how "great wits and madness" relate.

SOCIETY AND VALUES -- Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 151 Principles of Economics 4R-OL-4C

Includes both microeconomics and macroeconomics. Analyzes market behavior. Considers production and pricing decisions under alternative industrial structures. Examines the determinants of economic growth, unemployment and inflation, including fiscal and monetary policy.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

Surveys learning, motivation, personality, intelligence, abnormal behavior, social behavior, perception, emotion, and psychobiology. Stresses objective analysis of behavior and provides a foundation for advanced courses.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 200 Career Preparation 1R-OL-1C W,S

This course is for economics majors, to be taken in the second or third year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resume preparation. Cross-listed with CHEM200, and MA200.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV 244 Music History: Medieval, Renaissance, Baroque 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 245 Music History: Classical, Romantic, Modern 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 272 Experimental Psychology 4R-OL-4C

Emphasizes experimental analysis of perception, motivation, learning, and personality. Programmed and independent experiments are performed. Laboratory periods are arranged.

SV 288 Introduction to Sociology 4R-OL-4C

Examine the social and historical construction of our personal identity based on race, class, and gender as well as how social and global inequality is associated with these categories.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R-OL-4C

Examines the ethical issues faced by professional engineers in the global corporate context. Deals with such topics as codes of ethics, professional autonomy, employer authority, and whistle blowing.

SV 304 Bioethics 4R-OL-4C

Introduces students to basic issues in bioethics such as physician-patient relationships, the conduct of research, cross-cultural concerns, and codes of ethics.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 350 Managerial Accounting 4R-OL-4C Prereq: SV 151

Covers accounting concepts and procedures for preparation of financial reporting. Emphasizes use of accounting as a tool for management control and decision making.

SV 351 Managerial Economics 4R-OL-4C Prereq: SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. In addition to SV 151, students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Prereq: SV 151

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Prereq: SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Prereq: SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Prereq: SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Prereq: SV 151

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Prereq: SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 373 Gender Issues 4R-OL-4C

Examines male-female differences in behavior, personality, emotion, and cognition. Examines how men and women differ as they pursue the goals of life and the degree to which these differences are innate or learned.

SV 375 Personality Theories 4R-OL-4C

Presents an organized summary of major contemporary theories of personality. Compares and contrasts theories of human behavior. Analyzes the degree that behavior is purposive, unconscious, instinctive, learned, modifiable, and predictable.

SV 382 Anthropology of Religion 4R-OL-4C

Examines various concepts and practices pertaining to the supernatural, focusing primarily on indigenous religions around the world. Discusses the relationships of religious beliefs, values, and practices with social organization, economic behavior, subsistence systems, and technology

SV 385 Archaeology & Prehistory 4R-OL-4C

Examines the human past through the analysis of cultural artifacts: the course focuses on the methods and techniques of archaeology and the study of the major cultural and social transformations from foraging to agricultural and complex civilizations.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and ongoing evolution: examines the evidence of the fossil record and genes, compares human behavior with other primates, considers physical basis for behaviors, and the extent and causes of human physical diversity..

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C Prereq: SV 151

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

COMMUNICATION

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis ofttexts and images,research methods, and theconventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Prereq: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

SPECIAL TOPICS AND DIRECTED STUDY

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX496 Seminar for HSS Senior Project 2R-OL-2C F Prereq: Economics or International Studies major and Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX497 Directed Study for HSS Senior Project 2R-OL-2C Arranged Prereq: XX496 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double majors.

MODERN LANGUAGES

(NOTE: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Prereq: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Prereq: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Prereq: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Prereq: GE 213

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Prereq: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C

Summer Prereq: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Prereq: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-OL-4C S

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-OL-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

HSS MAJORS

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning Outcomes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 - A. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 - B. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 - C. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 - A. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 - B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 - A. Assemble and evaluate resources for research in international studies.

- B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA233 World Literature
GS163International Relations
GS285Humans and Culture
GS291World Geography
SV151 Principles of Economics
GS223World History

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

- a. International Political Economy: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose at least three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General List

IA353 History of Economic Thought
GS322Industrial Revolution in a Global Context
GS350International Trade and Globalization
GS351International Finance
GS352Economic Growth and Development
GS361Politics of the Global Economy
SV328Comparative Business History
SV354 Environmental Economics

Regional List

GS128Introduction to East Asia
GS161Comparative Politics
GS222Modern Latin American
GS366European Union
GS363European Politics and Government
GS399Geography of the Middle East
GS492Geography of Africa

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

- a. Comparative Cultures: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322Industrial Revolution in Global Context

GS333Travel in World Literature
GS334Global Novel in the 20th Century
GS432Literature of the Global Economy
GS462Postcolonial Literature
SV191 Cultural Geography
SV201 Religion and Ecology
SV226 The West in the East
SV382 Anthropology of Religion

Regional list (including but not limited to the following courses)

IA311 Topics in German Culture I
GS128Introduction to East Asia
GS207Asian Religions and Philosophy
GS222Modern Latin America
GS313Contemporary Spain
GS327Modern China
GS335Arabic Literature
GS379Japanese Culture
GS391Contemporary Europe
GS442Art History: Renaissance to Modern
GS492Geography of Africa

1. Individualized Major: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS MINORS

MINOR IN ANTHROPOLOGY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

1. Five Courses in Anthropology.
 2. The following three courses are required:
 - o GS 285 Humans & Culture
 - o SV 385 Archaeology & Prehistory
 - o SV 386 Human Evolution
- A minimum of 40 credits in HSS courses must be earned to obtain the minor.
 - Substitutions may be made with the approval of the Minor Advisor

Courses

- o GS 384 Japanese Society
- o SV 382 Anthropology of Religion
- o XX 399 Special Topics
- o XX 499 Directed Study

MINOR IN ART

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

1. Five Courses in Art:
 - a. The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242
 2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
 3. Substitutions may be made with the approval of the Minor Advisor
- Courses
- o GS442 Art History: Renaissance to Modern
 - o IA142 Drawing
 - o IA148 Beginning Photography
 - o IA244 Design and Color
 - o SV242 Visual Arts in Civilization

MINOR IN EAST ASIAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - o GS128 Introduction to East Asian History
 - o GS207 Asian Religions and Philosophy
 - o GS324 Gender and Work in China
 - o GS327 Modern China
 - o GS384 Japanese Society
 - o SV226 The West in the East
 - o SV326 Overseas Chinese
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN ECONOMICS

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Principles of Economics (SV 151);
 - b. Intermediate Microeconomics (IA 350) and Intermediate Macroeconomics (IA 351);
 - c. Two additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- o GS350 International Trade and Globalization
- o GS351 International Finance
- o GS352 Economic Growth and Development
- o IA350 Intermediate Microeconomics
- o IA351 Intermediate Macroeconomics
- o IA352 Game Theory
- o IA353 History of Economic Thought
- o IA450 Mathematical Economics
- o IA453 The Entrepreneur
- o SV151 Principles of Economics
- o SV350 Managerial Accounting
- o SV351 Managerial Economics
- o SV352 Money and Banking
- o SV353 Industrial Organization

- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX499 Directed Study

MINOR IN EUROPEAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS313 Contemporary Spain
 - GS337 Shakespeare's Europe
 - GS363 European Politics and Government
 - GS366 The European Union
 - GS431 Literary London
 - GS469 Contemporary British Fiction and Film
 - GS491 Geography of Europe
 - IA311 Topics in German Culture I
 - IA337 European Romanticism
 - SV222 Western Civilization to 1500
 - SV223 Western Civilization from 1500 to the Present
 - SV291 Medieval Europe
 - SV413 Contemporary Germany
 - XX399 Special Topics
 - XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN GEOGRAPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS191 Geography of Middle East
- GS222 Modern Latin America
- GS291 World Geography
- GS327 Modern China
- GS391 Contemporary Europe
- GS491 Geography of Europe
- GS492 Geography of Africa
- SV191 Cultural Geography
- SV291 Medieval Europe
- XX399 Special Topics
- XX499 Directed Study

MINOR IN HISTORY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS128 Introduction to East Asian History
- GS221 Colonial Latin America
- GS223 World History
- GS222 Modern Latin America
- GS324 Gender and Work in China
- GS327 Modern China
- GS422 Industrial Revolution in Global Context
- IA388 Chinese Nationalism
- SV222 Western Civilization to 1500
- SV223 Western Civilization since 1500
- SV226 The West in the East
- SV322 Disasters and Modern Society since 1700
- SV326 Overseas Chinese
- SV328 Comparative Business History
- SV329 Cities in Latin American History
- XX399 Special Topics
- XX499 Directed Readings

MINOR IN LANGUAGE AND LITERATURE

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and HS330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS237 Science Fiction
- GS334 Travel in World Literature
- GS335 The Global Novel in the Twentieth Century
- GS336 Literature of War
- GS337 Shakespeare's Europe
- GS338 Contemporary Arabic Literature in Translation
- GS412 Topics in German Culture II
- GS431 Literary London
- GS432 Literature and Film of the Global Economy
- GS462 Postcolonial Literature
- GS469 Contemporary British Fiction and Film
- IA230 Fundamentals of Public Speaking
- IA231 Introduction to Poetry
- IA232 African American Music in American Literature
- IA233 World Literature
- IA234 Major American Writers
- IA236 Jane Austen and the Rhetoric of Fiction
- IA237 Introduction to Drama
- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature

- IA337 European Romanticism
- IA339 Rebellion in American Literature
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Masculinity and Work in Fiction and Film
- SV334 Utopian Thought and Literature
- SV336 Contemporary American Fiction
- SV337 20th century American Novel
- SV339 Literature and the Environment
- SV234 The American Dream
- XX399 Special Topics
- XX499 Directed Study

MINOR IN LATIN AMERICAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS221 Colonial Latin America
 - GS222 Modern Latin America
 - GS323 The Andean Countries of South America
 - GS313 Contemporary Spain
 - IA332 Don Quixote
 - SV329 Cities in Latin American History
 - SV338 Latin American Fiction: The Boom and Beyond
 - XX399 Special Topics
 - XX499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN MODERN LANGUAGES (GERMAN, JAPANESE, AND SPANISH)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture
IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation
Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413
Japanese Language and Culture X/XI/XII

XX 399 Special Topics

XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.

Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

MINOR IN MUSIC

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. A minimum of 40 credits must be earned to obtain the minor. 36 of these credits must be in HSS courses. The remaining four (4) credits may be in an approved course from outside the HSS Department.
2. The following four courses are required:
 - o SV244 Music History: Medieval, Renaissance, Baroque
 - o SV245 Music History: Classical, Romantic, Modern
 - o IA246 Music Theory I: Concepts
 - o IA346 Music Theory II: Applications

To fulfill the fifth course requirement for the Area Minor in Music, the candidate may choose ONE of the following options:

- a. A course from outside the HSS Department, approved by the Minor Advisor, such as:
 - o ECE481 Electronic Music Synthesis
 - o PH404 Acoustics
 - o PH460 Directed Study (music-related)
- b. IA 499: Directed Study in Music. Pre-requisite: consent of the Minor Advisor.
- c. A 348: Music Performance. Pre-requisite: consent of the Minor Advisor.
- d. Four (4) credits of Satisfactory participation in one or more of the formal Performing Groups (Concert Band, Jazz Ensemble, String Ensemble, and Chorus) are required. Performance credit may not be transferred from another college. One academic term of satisfactory participation earns one credit. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for "satisfactory participation" will be provided to the candidate by the Minor Advisor.

MINOR IN PHILOSOPHY AND RELIGION

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy and Religion has the following requirements:

1. Five courses in Philosophy and Religion, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- o GS207 Asian Religions and Philosophy
- o IA101 Introduction to Philosophy
- o IA302 Philosophy of Religion
- o IA335 Bible as Literature
- o SV201 Religion and Ecology
- o SV303 Business and Engineering Ethics
- o SV304 Bioethics
- o SV382 Anthropology of Religion
- o XX399 Special Topics
- o XX499 Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS161 Comparative Politics
- GS163 International Relations
- GS361 Politics of the Global Economy
- GS366 The European Union
- GS363 European Politics and Government
- SV166 American Politics and Government
- SV369 British Politics and Government
- SV463 Seminar on America's Future
- XX399 Special Topics
- XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Five courses in Psychology, distributed as follows:
 - Principles of Psychology (SV 171).
 - Experimental Psychology (SV 272).
 - Three other Psychology courses.
2. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Courses

- IA471 Literature of Madness
- SV171 Principles of Psychology
- SV272 Experimental Psychology
- SV375 Personality Theories
- SV373 Gender Issues
- XX399 Special Topics
- XX499 Directed Study

GERMAN TECHNICAL TRANSLATOR’S CERTIFICATE PROGRAM

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute’s degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student

will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60



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Current Students
Incoming Freshman

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Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

Programs of Study

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Military

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student’s choice of commissioning program and Army requirements.

CURRICULUM

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College,

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

Freshman Year

			Credit
MS	101	Leadership and Personal	1
MS	102	Development	1
MS	103	Introduction to Tactical Leadership	1
		Basic Tactical Leadership	

Sophomore Year

			Credit
MS	201	Innovative Team	2
MS	202	Leadership	2
MS	203	Foundations of Tactical Leadership	2
		Foundations of Tactical Leadership II	

Summer			Credit
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MS	206	ROTC Basic Camp	0
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ADVANCED COURSE

Junior Year

			Credit
MS	301	Adaptive Team Leadership	4
MS	302	Leadership Under Fire	4
MS	303	Leadership Under Fire II	4

Senior Year

			Credit
MS	401	Developing Adaptive	4
MS	402	Leaders	4
MS	403	Leadership in a Complex World	4
		Leadership in a Complex World II	

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training..



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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose- Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

Rose-Hulman

https://www.rose-hulman.edu/course-catalog/course-catalog-2013-2014/programs-of-study/pre-professional-programs.aspx[1/20/2017 12:41:13 PM]



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[Trustees](#)
[Parents](#)

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Course Descriptions

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Aerospace Studies (Air Force ROTC)

LT Col Adkins, MAJ Parks, CAPT Blystone

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Prereq: None

This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Prereq: AS 101 or instructor permission

This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Prereq: AS 102 or instructor permission

This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Prereq: Enrollment in AS 101, AS 102, or AS 103

Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Prereq: AS 103 or instructor permission

This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Prereq: AS 201 or instructor permission

This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Prereq: AS 202 or instructor permission

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

This course is a continuation of the winter quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Prereq: Enrollment in AS 201, AS 202, or AS 203

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Prereq: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Prereq: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Prereq: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Prereq: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Prereq: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Prereq: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Prereq: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Prereq: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Applied Biology & Biomedical Engineering

Applied Biology

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed AB110, AB120 or AB130 cannot receive credit for taking AB101.

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for AB or BE majors and not as an AB elective.

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed AB course.

The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for AB205 cannot earn credit for AB210 or AB230 without departmental consent.

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

Discusses the essential properties of eubacteria and archaea. Bacterial nutrition, growth, genetics and structural

Sophomore Engineering

and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

AB 230 Eukaryotic Cell and Molecular Biology 3R-3L-4C S Prereq: AB 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

AB 264 Introduction to Environmental Science 4R-0L-4C W Prereq: CHEM 111, or CHEM 105 or CHEM 201, or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

AB 310 Plant Structure & Function 3R-3L-4C S Prereq: AB 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

AB 320 Ecology 3R-3L-4C F Prereq: AB 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

AB 330 Evolutionary Biology 4R-0L-4C W Prereq: AB 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

AB 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Prereq: AB120, and Jr/Sr standing or consent of instructor

Designed to introduce applied biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

AB 399 Practice of Science 4R-0L-4C Prereq: RH330 and MA223, or consent of instructor

This course focuses on skills required for implementing scientific research, including reading the primary literature, experimental design, scientific writing, oral presentations, research proposal writing, poster presentations, and investigation of research programs (through seminars or individual meetings). Each student chooses a project and research mentor by the end of the course.

AB 410 Infection and Immunity 4R-0L-4C Arranged Prereq: AB 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

AB 411 Genetic Engineering 4R-0L-4C Arranged Prereq: AB 205 or AB 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

AB 421 Applied Microbiology 4R-0L-4C Arranged Prereq: AB110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

AB 431 Genomics and Proteomics 4R-0L-4C S Prereq: AB 205 or AB210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

AB 441 Virology 3R-3L-4C Prereq: AB110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

AB 451 Cancer Biology 4R-0L-4C Prereq: AB 205 or AB210 or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

AB 461 Evolutionary Medicine 4R-0L-4C Arranged Prereq: AB130, and AB205 or AB210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

AB 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged Prereq: AB 205 or AB210 or consent of instructor

Strategies and methods used to identify and understand the genetic and molecular bases of inherited human disease are addressed. Topics include, human population genetics, pedigrees, genetic and physical mapping of human genes, linkage analysis, and diagnostic testing. Primary literature is routinely utilized.

AB 491 Special Topics in Applied Biology XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed AB course.

AB 492 Directed Study in Applied Biology XR-XL-XC Arranged Prereq: Consent of instructor

Covers applied biology material of mutual interest to the student and instructor which cannot be experienced in any other listed AB course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the ABBE department is required to use this course to fulfill AB elective credit requirements.

AB 496 Senior Thesis Research I 0R-6L-2C F,W,S Prereq: AB 399 and consent of instructor

Initiation of senior thesis under the direction of an ABBE faculty mentor. Major tasks include creation and submission of a research proposal and piloting procedures. Additional requirements for adequate progress determined by each faculty mentor.

AB 497 Senior Thesis Research II 0R-12L-4C F,W,S Prereq: AB 399 and consent of instructor

Continuation of research under the direction of an ABBE faculty mentor. Major tasks include data acquisition and methodological refinement. Additional requirements for adequate progress determined by each faculty mentor.

AB 498 Senior Thesis Research III 0R-12L-4C F,W,S Prereq: AB 399 and consent of instructor

Continuation of research under the direction of an ABBE faculty mentor. Major tasks include data acquisition and preliminary analysis. Additional requirements for adequate progress determined by each faculty mentor.

AB 499 Senior Thesis Research IV 0R-6L-2C W Prereq: AB 399 and consent of instructor

Completion of senior thesis under the direction of an ABBE faculty mentor. Major tasks include final analysis, public presentation of results, and submission of the written thesis. Additional requirements for adequate progress determined by each faculty mentor.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4C W Prereq: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE201 Biomedical Measurements 3R-3L-4C Prereq: BE100, ES203

Discuss the measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors (temperature, force, pressure, velocity, etc), and basics of microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I 3R-3L-4C W Prereq: AB120, AB205

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Prereq: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents

manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of cradle to cradle design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II 3R-3L-4C S Prereq: BE310

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3C W Prereq: ES 201, EM 204, and BE 201, or consent of instructor Co: BE351 and BE361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Instrumentation and Signal Processing 3R-3L-4C F Prereq: BE 201, ES 203

This course introduces the fundamental of biomedical signal processing strategies. Topics include data acquisition, A/D and D/A conversion, digital filter design, time-frequency analysis, and I/O interfaces. Multichannel data processing and high dimensional data analysis techniques are also covered. Lectures will be accompanied by data analysis assignments and projects using MATLAB, LabVIEW, and microcontrollers.

BE 350 Biocontrol Systems 4R-0L-4C Prereq: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE 351 Biomedical Engineering Lab 1R-3L-2C Prereq: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE331 and BE361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE 352 Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 353 Biomaterials Lab 0R-3L-1C Prereq: ES 201, EM 204, and BE 201, or consent of instructor. Coreq: BE361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Prereq: BE 201, Coreq: EM204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 400 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Prereq: BE390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Prereq: BE410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Prereq: BE420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 482 Bioengineering Statistics 4R-0L-4C Prereq: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Prereq: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Prereq: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F,W,S Prereq: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing 3R-3L-4C W Prereq: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Human Physiology A 3R-3L-4C W Prereq: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Human Physiology B 3R-3L-4C S Prereq: Junior, Senior, Graduate standing or consent of

instructor

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Prereq: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Prereq: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3 R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 535.

BE 539 Multiscale Biomechanics 3R-3L-4C Prereq: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and BE340, or BE340 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as ECE584.

BE 543 Neuroprosthetics 3R-3L-4C Prereq: BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Prereq: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Prereq: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Prereq: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Prereq: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 565 Experimental Methods in Tissue-Biomaterial Interactions 3R-3L-4C S Prereq: BE 361, or consent of instructor

This course focuses on teaching students experimental methods used for investigations of tissue-biomaterial interactions. Topics include bioethics issues associated with experiments on cells, tissues, animals, and people; biosafety issues associated with cells/tissues from animals and humans; the design, critique, and statistical analysis of experiments. Students conduct hands-on investigations of cell-biomaterial interactions which require the use of common laboratory equipment, aseptic technique, mammalian cell culture, and current molecular methods to investigate cell viability, structure, and function.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Prereq: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 Selected Topics F,W,S

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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Course Descriptions

Minors

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Advanced Placement

Graduate Studies

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Chemical Engineering

Professors Artigue, Coronell, Hariri, D. Henthorn, K. Henthorn, McClellan, Nolte, Sauer, and Serbezov.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Prereq: None
An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 1R-0L-0C F Prereq: sophomore standing in Chemical Engineering
Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F Prereq: CHEM 113 or concurrent registration in CHEM 112, MA 113 or concurrent registration, and PH 111 or concurrent registration
An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Prereq: CHE 201
The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 300 Career Preparation II 0L-0C F Prereq: Junior standing in Chemical Engineering
Career choices; preparation of resume; preparation for summer positions; preparation for graduate programs. 2-5 contact hours per quarter.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Prereq: CHE 201
Physical properties of fluids, fluid statics, laminar and turbulent flow, boundary layer concept, flow past objects and flow through porous media. Design of pipe networks and pumps. High speed ideal gas flow. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Prereq: CHE 202, MA211 Coreq: CHE110
First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F,W Prereq: CHE 303, MA212
Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Prereq: CHE 110, MA211, MA212 or

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

concurrent enrollment

The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Prereq: CHEM 115 or consent of instructor

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Prereq: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304

Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Prereq: CHE 320, CHE 304

Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Prereq: CHEM 360 and CHE 304

The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Prereq: Senior Standing in Chemical Engineering

Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Prereq: CHE 321, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Prereq: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Prereq: CHE 321

Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Prereq: CHE 416, CHE 404

Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Prereq: CHE 417 or

consent of instructor

Completion of an open-ended design project that will include written and oral communication of intermediate results and a final written report.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W Prereq: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F Prereq: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 450 Air Pollution 4R-0L-4C F or W Prereq: Junior or Senior standing

An introduction to air pollution and its control with special emphasis on the engineering aspects. Discussions of meteorology, health effects, sources and types of pollution, industrial control technology. Student projects. Cross-listed with CE561.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Prereq: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Prereq: CHE 303 or CHEM361 or ME201 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S Prereq: CHE303

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F,W,S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F,W,S Prereq: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

UNDERGRADUATE-GRADUATE COURSES

CHE 502 Transport Phenomena I 4R-0L-4C Prereq: CHE 321 or consent of instructor

Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 503 Transport Phenomena II 4R-0L-4C

Energy Transport: multidimensional systems; macroscopic balances for nonisothermal systems. Mass Transport: fundamentals of ordinary diffusion, multicomponent diffusion, pressure and thermal diffusion, coupled heat and

mass transfer, boundary layer analysis, turbulent transport, mass transfer coefficients, macroscopic balances.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W (proposed) Pre: CHE 321 or consent of instructor

Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Cross-listed with EP 511, ME 519, and ECE 519.

CHE 521 Advanced Chemical Engineering Computation 4R-0L-4C

The application of advanced mathematics to chemical engineering problems. The topics include: the formulation of the partial differential equations of kinetics and heat, mass and momentum transfer problems; series solution techniques; transform solution techniques; vector formulation; numerical methods for systems of differential equations; optimization, including linear programming, combinatorial optimization, and stochastic optimization techniques.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: AB110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: AB110, CHE 321 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Course Descriptions

Minors

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Advanced Placement

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Chemistry and Biochemistry

Professors Adcock, Allison, Brandt, R. DeVasher, Erwin, Morris, Mottel, Mueller, Sunahori, Tilstra, Weatherman and Wilson.

CHEM 111 General Chemistry I 3R-3L-3C F,W,S Prereq: None; Coreq: CHEM111L
Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 111L General Chemistry I Laboratory 0R-3L-1C F,W,S Prereq: None; Coreq: CHEM111
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM111 recitation.

CHEM 112 Chemistry Honors 4R-3L-5C F Prereq: Advanced placement
An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-3C W,S Prereq: CHEM 111 and CHEM111L; Coreq: CHEM113L
Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 113L General Chemistry II Laboratory 0R-3L-1C W,S Prereq: CHEM111 and CHEM111L; Coreq: CHEM113
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 115 General Chemistry III 3R-3L-3C W,S Prereq: CHEM 113 and CHEM113L, or CHEM 112; Coreq: CHEM115L
Topics in this course include acid-base reactions, electrochemistry, and coordination chemistry.

CHEM 115L General Chemistry III Laboratory 0R-3L-1C W,S Prereq: CHEM113 and CHEM113L or CHEM112; Coreq: CHEM115
Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM113 recitation.

CHEM 200 Career Preparation 1R-0L-1C W
This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with MA200, and SV200.

CHEM 225 Analytical Chemistry 3R-3L-3C F, S Prereq: CHEM 115 and CHEM115L; Coreq: CHEM225L
This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry**
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 225L Analytical Chemistry Laboratory 0R-3L-1C F, S Prereq: CHEM 115 and CHEM115L; Coreq: CHEM225

This course represents the laboratory component of analytical chemistry. Practicums are part of the grade along with reports.

CHEM 251 Organic Chemistry I 3R-0L-3C F Pre: CHEM 113 and CHEM113L, or CHEM112; Coreq: CHEM251L

An introduction to the classification of organic compounds, their structural features, including stereochemistry, and concepts related to reaction mechanisms and synthetic methods.

CHEM 251L Organic Chemistry I Laboratory 0R-3L-1C F Prereq: CHEM113 and CHEM113L, or CHEM112; Coreq: CHEM251

Organic Laboratory techniques are developed along with appropriate spectroscopic methods. Assessment is in part via practicums. Computational chemistry methods and green chemistry approaches are also introduced.

CHEM 252 Organic Chemistry II 3R-0L-3C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM 252L

Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis, and an introduction to the methods used to determine structure, including IR and NMR spectroscopy and mass spectrometry.

CHEM 252L Organic Chemistry II Laboratory 0R-3L-1C W Prereq: CHEM 251 and CHEM 251L; Coreq: CHEM252

A continuation of CHEM251L where additional, more complicated synthetic techniques and methods along with additional spectroscopic techniques are introduced. Assessment is in part via practicums.

CHEM 253 Organic Chemistry III 3R-0L-3C S Prereq: CHEM252 and CHEM252L; Coreq: CHEM 253L

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 253L Organic Chemistry III Laboratory 0R-4L-1C S Prereq: CHEM252 and CHEM252L; Coreq: CHEM253

Project based laboratory where techniques and skills developed in the previous organic laboratories are applied to more open-ended problems.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Prereq: CHEM111 and CHEM111L

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with AB264.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Prereq: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Prereq: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research performed under the direction of a faculty member selected by mutual agreement. This course is designed for research performed before taking CHEM291. Students may register for 1 to 2 credit hours per quarter.

CHEM 291 Introduction to Chemical Research 3R-3L-4C W Prereq: CHEM 113 or CHEM113L, or CHEM 112

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members.

CHEM 304 Glassblowing 1R-3L-1C S Prereq: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Prereq: CHEM225 and CHEM225L

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Prereq: CHEM225 and CHEM225L

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Prereq: CHEM 252

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Prereq: CHEM330 and AB210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C W, S Prereq: CHE303, CHE 304, and CHEM115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Prereq: CHEM115, CHEM115L, MA212 and MA381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Prereq: CHEM111, CHEM111L, MA212, PH112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 371 Environmental Analytical Chemistry 3R-4L-4C F Prereq: CHEM251 and CHEM251L (or concurrent enrollment), and CHEM225 and CHEM225L and CHEM 264

This course is a laboratory-driven course where processes involved in performing environmental analytical chemistry are addressed. The focus of this course is on the chemical principles, analytical theory, instrumentation, and methods employed to quantitatively and qualitatively analyze pollutants in soil, water, biological tissues, and the atmosphere. Several techniques will be included in the course: sampling (obtaining a representative sample of complex system); sample preparation (extraction, clean-up, pre-concentration, derivitization, digestion, etc.); data acquisition (The laboratory will include use of EPA/ASTM methods/protocols, method development, etc.); and data handling and analysis (statistics, signals, noise, etc.).

CHEM 400 Chemical Communication I 1R-0L-1C W Prereq: CHEM291

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. The emphasis of this course is to provide instruction in written communication. The fundamental skills useful for composition of professional chemistry communications is introduced culminating in a research prospectus. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 401 Chemical Communication II 1R-0L-1C F Prereq: CHEM400 and CHEM490

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. Students will learn methods associated with constructing results and analysis sections of formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 402 Chemical Communication III 1R-0L-1C W Prereq: CHEM401

The emphasis of this course is to provide instruction in oral communication. Students will be taught fundamental

skills useful for public presentation of research and its results. Students will also be required to attend the chemistry department's seminar series.

CHEM 403 Chemical Communication IV 1R-0L-1C S Prereq: CHEM402

Students will publish a thesis and deliver a professional seminar on their undergraduate research.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Prereq: CHEM330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 431 Biochemical Instrumentation 3R-4L-4C Prereq: AB210 and CHEM330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 433 Biochemistry Laboratory 0R-3L-1C S Prereq: CHEM330

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Prereq: CHEM252 and CHEM362 or CHEM360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Prereq: CHEM441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 445 Organometallic Chemistry 4R-0L-4C S Prereq: CHEM252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 451 Organic Structure Determination 2R-8L-4C S Prereq: CHEM253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 452 Synthetic Organic Chemistry 4R-0L-4C F or W Prereq: CHEM253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 454 Theoretical Organic Chemistry 4R-0L-4C W Prereq: CHEM253 and CHEM361 or CHEM360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 455 Natural Products 4R-0L-4C Prereq: CHEM253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 457 Synthetic Polymer Chemistry 4R-0L-4C Prereq: CHEM252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 461 Advanced Physical Chemistry 4R-0L-4C Prereq: CHEM363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 462 Physical Polymer Chemistry 4R-0L-4C Prereq: CHEM 361 or CHE303

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Prereq: CHEM251 or CE564 or consent of

instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: permission of instructor
Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F,W,S Prereq: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.
Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F,W,S Prereq: Permission of instructor
Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Prereq: CHEM291
Research performed under the direction of a faculty member selected by mutual agreement. Students may register for 1 to 3 credit hours per quarter.



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Minors

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Civil Engineering

Professors Aidoo, Chapman, Hanson, Kershaw, Lovell, Mueller, Price, Robinson, and Sutterer

CE 101 Engineering Surveying 0R-6L2C S Prereq: None

Covers basic principles and practices of surveying. Measurement through the application of surveying techniques; theory of errors and their analysis; concepts of horizontal, vertical, and angular measurement; coordinate systems; basic surveying operations and computations; reading and interpretation of building, highway, and/or bridge plans; traverse computations; applications to construction and design.

CE 111 Geographical Information Systems 2R-0L-2C W Prereq: None

The course covers introductory concepts of geographical information systems and related technologies. Topics covered will relate to the use, collection, creation, and analysis of spatial data in applying GIS and related technologies to civil engineering projects.

CE 250 Sustainable Civil Engineering Design 2R-0L-2C S Prereq:

An introduction to sustainable design of civil engineering systems. Includes treatment of current issues as they relate to design and construction for economic, environmental and social aspects of civil engineering.

CE 303 Engineering Economy 4R-0L-4C W Prereq: Senior class standing

Emphasizes time value of money and factors related thereto. Familiarizes students with concepts of annual cost, present worth, and minimum rate of return as tools for consideration of economic factors pertinent to the selection of alternate solutions to engineering problems.

CE 310 Civil Engineering Numerical Methods 2R-0L-2C S Prereq: MA 212

Covers numerical methods used in solution of engineering problems. Typical topics include root finding, numerical integration, numerical differentiation, curve fitting, and numerical solution of ordinary differential equations. Departmental Impact: The department is confident student learning in advanced Excel and Mathcad usage to solve civil engineering problems can be improved if it is incorporated into assignments across the curriculum. The department will implement a plan across the curriculum for intentional learning about advanced Excel and Mathcad usage with the adoption of this change. The details of this plan are not available at this time but the department is confident this intentional learning across the curriculum will be more effective than the current approach to learning this content.

CE 320 Civil Engineering Materials 3R-3L-4C S

A study of the origin, nature, performance and selection criteria of various basic materials used in the practice of civil engineering. These include aggregates, portland cement, concrete, and bituminous materials. Emphasis will be placed on standard methods of testing and characterization as related to the mechanical behavior of materials.

CE 321 Structural Mechanics I 4R-0L-4C F Prereq: EM 203

Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Prereq: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory investigation of soil properties.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

CE 371 Hydraulic Engineering 3R-3L-4C F Prereq: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE380 Introduction to Transportation Engineering 4R-0L-4C S Coreq: MA223, CE320

Study of transportation functions and transportation systems; measuring and estimating demand; characteristics of transportation modes, interactions between modes, and mode interfaces; social, environmental, technological, economic, and public policy impacts; techniques of transportation system planning, design, and operation, with an emphasis on highway geometric design.

CE 400 Career Preparation Seminar 1R-0L-0C S Prereq: CE 489

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 410 Senior Project 0R-8L-4C On Demand Prereq: Senior class standing

Gives the student the opportunity to work on a civil engineering design or research project of the student's own choice, but which has met the approval of the staff prior to the start of the quarter. Requires presentation of oral and written reports. Not a regular elective offering.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Prereq: CE 321

Matrix methods of structural analysis for two- and three- dimensional indeterminate structures. Force method, stiffness method, introduction to finite element analysis for civil engineers.

CE 430 Structural Design in Timber I 4R-0L-4C On Demand Prereq: CE 321

Presents the analysis and design of modern structures constructed of timber. Considers fasteners and their significance in design. Develops design criteria and their application to plane and three dimensional structures.

CE 431 Structural Design in Steel I 3R-0L-3C S Prereq: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Prereq: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 436 Foundation Engineering 4R-0L-4C S Prereq: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Prereq: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C F Prereq: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 444 Pavement Design and Highway Construction 4R-0L-4C On Demand Prereq: CE 320

Introduction to analysis and design of rigid and flexible pavement systems; subgrade, subbase, base and surfaces; specifications, material testing and construction methods for soil stabilization, flexible and rigid pavements; pavement evaluation, maintenance and reconstruction.

CE 445 Construction Methods and Equipment 4R-0L-4C F Prereq: CE 201 and CE 336, Coreq: CE 442

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major

building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Prereq: CE 431 & CE 432

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will also look at environmentally safe and renewable building materials, energy efficient construction techniques, indoor air quality and moisture problems, etc. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Prereq: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Coreq: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 471 Water Resources Engineering 4R-0L-4C W Prereq: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Transportation Planning 4R-0L-4C On Demand Prereq: Junior class standing

Analyzes the transportation planning process. Stresses goals and approaches to solutions as related to the urban transportation problem. Includes a class project.

CE 481 Transportation Engineering 4R-0L-4C W Prereq: Senior class standing

Study of transportation functions and transportation systems including land, air and marine modes; transportation system elements including travel way, vehicle, controls and terminals; emphasis on highway geometric design.

CE 482 Urban Planning 4R-0L-4C On Demand Prereq: Junior class standing

Applies general principles of systems analysis and control to urban and regional planning. Covers human settlements, location theory, simulation, plan formulation, selection and implementation. Includes a class project.

CE 486 Civil Engineering Design & Synthesis I 1R-3L-2C F Prereq: RH 330, CE 460; Coreq: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be initiated by small teams of students to implement principles used in planning, design, and synthesis. Learning objectives include contracting, concept development, concept feasibility, planning and scheduling design work, data collection for subsequent design.

CE 487x Technical System Design & Synthesis 2R-2L-2C W Prereq: CE486; Coeq: CE 488

Technical system design of subdisciplinary elements of civil engineering projects submitted by corporate and governmental sponsors will be completed by individual team members to fulfill the needs of a team project initiated with CE486 and continuing in CE488. The "x" will be used to identify subdiscipline designation (c = general civil design, e= environmental, g = geotechnical, s = structural, t = transportation, w = water resources).

CE 488 Civil Engineering Design & Synthesis II 1R-2L- 2C W Prereq: CE486; Coreq: CE 487

Project management by small teams for civil engineering projects submitted by corporate and governmental sponsors will continue. Learning objectives include coordinate of major design work in subdisciplines, progress reporting to the client, critical path model management to keep the project on schedule to fulfill the needs of a team project initiated with CE486 and continuing in CE487.

CE 489 Civil Engineering Design & Synthesis III 1R-3L-2C S Prereq: CE 487, CE488

Civil engineering projects submitted by corporate and governmental sponsors will be completed. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. Learning objectives include construction planning and cost, final reporting, and public presentation of findings.

CE 490 Directed Studies 1-4C Arranged. F,W,S Prereq: Approval of department head, adviser, and course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

UNDERGRADUATE-GRADUATE COURSES

CE 520 Structural Engineering Practicum 0R-12L-4C Prereq: Grad or consent of instructor

Structural engineering practicum approved by the department.

CE 521 Matrix Methods for Structural Analysis 4R-0L-4C F Prereq: CE 321

Derivation of the direct stiffness method for truss and frame elements. Derivation of the finite element method for 2D plate elements. Requires development of computer programs to implement the direct stiffness method.

CE 522 Structural Dynamics 4R-0L-4C F Pre: Grad or consent of instructor Co-Req: CE 521

Analysis and behavior of structural members and systems subject to dynamic loads including basic theory for single-degree-of-freedom and multi-degree-of-freedom analytical models of civil engineering structures; seismic hazard analysis and methods of analysis for seismic loads; response spectra; time history; and linear and nonlinear methods.

CE 523 Advanced Solid Mechanics 4R-0L-4C W Prereq: Grad or consent of instructor and CE 522 The fundamentals of elasticity are introduced and related to various problems such as beams on elastic foundations, unsymmetrical bending, torsion of thin walled members, and curved beams. Introduction to the analysis and modeling techniques for existing and repaired structures. Design of retrofit measures for a variety of structures using advanced composite materials.

CE 524 Building Design 4R-0L-4C S Prereq: Grad or consent of instructor and CE523

Advanced structural analysis and design concepts for buildings: material nonlinearity, plastic design, pushover analysis, bracing, floor vibrations. Course culminates in a design project.

CE 525 Bridge Engineering 4R-0L-4C S Prereq: CE 321

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Introduces concepts of bridge engineering by providing the students with the necessary knowledge and skills to apply the AASHTO LRFD specifications for the analysis and design of highway and bridge superstructure components.

CE 530 Structural Design in Timber II 4R-0L-4C On Demand Prereq: CE 430

Presents the analysis and design of structures constructed of timber. Tapered beams, curved beams, box beams, stressed-skin panels, tapered columns, built-up columns, laminated arches, plate connected trusses, pole structures, diaphragms, shearwalls.

CE 532 Structural Design in Concrete II 3R-3L-4C F Prereq: CE 432

Advanced topics in reinforced concrete analysis and design such as serviceability. slender columns, two-way slabs, and strut-and-tie modeling.

CE 533 Connections and Detailing 4R-0L-4C S Prereq: CE 431 and CE 432

Analysis and design of structural systems with emphasis on detailing requirements; behavior of bolted and welded connections, including gusset plates, moment-resistant connections, and simple connections; design and analysis of base plate and anchoring systems; and an introduction to seismic detailing requirements.

CE 534 Structural Design in Masonry 4R-0L-4C On Demand Prereq: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C On Demand Prereq: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Prereq: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 537 Structural Design in Steel II 4R-0L-4C On Demand Prereq: CE 431

Covers the analysis and design of the various elements of a steel structure within the framework of the total structure. Includes composite design, plate girders, and multi-story building frames.

CE 561 Air Pollution 4R-0L-4C W Prereq: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Treatability Studies 2R-6L-4C On Demand Prereq: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 563 Unit Operations in Environmental Engineering 4R-0L-4C F Prereq: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Prereq: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Prereq: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Prereq: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Prereq: CE 471

Environmental planning and management strategies are examined using computer simulation models. Students will be introduced to some of the most widely used models in the fields of hydrology, hydraulics, and stormwater quality (nonpoint source pollution).

CE 568 Applied Contaminant Transport Modeling 4R-0L-4C On Demand Prereq: CE 460 or consent of instructor

Environmental planning and management strategies are examined using computer simulation models. Emphasis is on pollutant transport in various media and emerging pollution issues. Students are introduced to some of the most widely used models in the field of environmental engineering. Students also develop at least one pollutant transport model using common software such as EXCEL, MATHCAD.

CE 569 Environmental Systems Optimization 4R-0L-4C Prereq: Senior or Graduate class standing

Application of the principles of operations research to constrained optimization of environmental systems. Typical topics include strategies for non-linear searches, linear programming, dynamic programming, etc.

CE 570 Fluid Mechanics in Water Resources Engineering 4R-0L-4C On Demand Prereq: CE 371

Presents steady and unsteady flow problems in open channels and pipes, problems dealing with laminar and turbulent boundary layers, and problems including diffusion and dispersion. There will be occasional laboratory work to demonstrate physical modeling in water resources engineering.

CE 573 Groundwater Analysis 4R-0L-4C Prereq: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Prereq: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Prereq: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Prereq: Permission of instructor


A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

College & Life Skills

CLSK 100 College and Life Skills 1R-0L-1C F Prereq: None
This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

CLSK 121 College English 4R-OL-4C Prereq: Consent of Instructor
Focuses on understanding the basic patterns and conventions of writing, enhancing reading skills and written comprehension, and improving verbal communication and oral comprehension. This course is intended for students for whom English is a second language. Students required to take CLSK121 must successfully complete the course prior to taking RH131.

CLSK 122 English Language and Culture in Academic Texts 3R-3L-4C Prereq: Consent of instructor required
Reviews English grammar and introduces and develops deeper understanding of academic vocabulary. Familiarizes students with essential essay structures in academia. Introduces academic readings in select topics of academic concern in American socio-culture. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 123 English Language in Academic Research and Composition 3R-3L-4C Prereq: Consent of instructor required
Introduces students to formal research and composition of research papers. Strengthen students' formal research and writing skills for research papers. Guides students through readings in academic journals and articles. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 124 English Language and Culture in Academic Speech, Presentation, and Argumentation 3R-3L-4C Prereq: Consent of instructor required
Emphasizes fluency in spoken English. Rehearses academic vocabulary. Prepares students for academic presentations including technology. Develops students' academic listening and note-taking skills focusing on topics of American socio-cultural study. Introduces students to Socratic discussion and argumentation. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 125 English Rhetoric and Culture in Academia 3R-3L-4C Prereq: Consent of instructor required
Prepares students for full-length lectures in courses related to their majors, focusing on oral rhetoric devices. The course does not satisfy any Rose-Hulman degree requirement.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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Course Descriptions

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Computer Science & Software Engineering

CSSE 232 Computer Architecture I 3R-3L-4C F, W Prereq: CSSE132, or CSSE120 and ECE130

- | |
|--|
| Aerospace Studies (Air Force ROTC) |
| Applied Biology & Biomedical Engineering |
| Chemical Engineering |
| Chemistry and Biochemistry |
| Civil Engineering |
| College & Life Skills |
| Computer Science & Software Engineering |
| Electrical & Computer Engineering |
| Engineering Management |
| Engineering Mechanics |
| Engineering Physics |
| Geology |
| Humanities and Social Sciences |
| Mathematics |
| Mechanical Engineering |
| Military Science (Army ROTC) |
| Multi-Disciplinary Studies |
| Optical Engineering |
| Physics |
| Robotics |
| Sophomore Engineering |

Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic, ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control. Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prereq: CSSE220 or CSSE221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE290 Special Topics in Computer Science 1 - 4C Arranged Prereq: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prereq: CSSE230 and MA275

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W,S Prereq: CSSE220 or CSSE221, and CSSE132 or CSSE232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prereq: MA275 and CSSE230 (or concurrent enrollment in CSSE230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prereq: CSSE220 or CSSE221, and MA212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 371 Software Requirements Engineering 3R-3L-4C F Prereq: CSSE230, RH330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requ: CSSE371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict

management. Professional issues including career planning, lifelong learning, software engineering ethics, and the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prereq: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Design 3R-3L-4C W Prereq: CSSE371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 3R-3L-4C S Prereq: CSSE374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prereq: CSSE230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prereq: CSSE332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prereq: CSSE304

A survey of some current and emerging programming languages, focusing on unique language paradigms-ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prereq: CSSE232, CSSE304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prereq: CSSE230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prereq: CSSE220 or CSSE221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 433 Advanced Database Systems 4R-0L-4C S Prereq: CSSE333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prereq: CSSE332 and MA275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and

integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prereq: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence R-0L-4C Arr Prereq: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prereq: CSSE220 or CSSE221, and MA212 (MA371 or MA373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prereq: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prereq: CSSE230 and MA375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 477 Software Architecture 4R-0L-4C F Prereq: CSSE374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 479 Cryptography 4R-0L-4C S Prereq: CSSE220 or CSSE221, and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prereq: CSSE230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE487 Senior Research Project I 4C Arranged Prereq: RH330 and senior standing

CSSE488 Senior Research Project II 4C Arranged Prereq: CSSE487

CSSE489 Senior Research Project III 4C Arranged Prereq: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arranged Prereq: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arr Prerequisite: Permission of instructor and department head
Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arranged Prereq: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arranged Prereq: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arranged Prerequisite: RH330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arranged Prerequisite: CSSE494

CSSE 496 Senior Thesis III 4C Arranged Prerequisite: CSSE495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Project I 4C F Prerequisite: CSSE371

CSSE 498 Senior Project II 4C W Prerequisite: CSSE 374 and CSSE497

CSSE 499 Senior Project III 4C S Prerequisite: CSSE498

Group software engineering project requiring completion of a software system for an approved client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure.



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Minors

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Advanced Placement

Graduate Studies

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Electrical & Computer Engineering

Professors Berry, Black, Chang, Doering, Grigg, Herniter, Hoover, Hudson, Kim, Miller, Moore, Mu, Padgett, Rostamkolai, Simoni, Song, Throne, Walter, Wheeler, and Yoder.

ECE 130 Introduction to Logic Design 4R-0L-4C F,W,S Prereq: None
Combinational logic analysis and design, Boolean algebra, gate-level optimization, switch-level circuits, propagation delay, and standard combinational components. Sequential circuit analysis and design, flip-flops, timing diagrams, registers, counters, and finite state machine controllers. Design projects using circuit simulator and implementation in hardware.

ECE 160 Engineering Practice 0R-4L-2C F,W Prereq: none
The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

ECE 203 DC Circuits 3R-3L-4C F,W,S Prereq: MA111 and PH112
Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

ECE 204 AC Circuits 3R-3L-4C F,W,S Prereq: ECE203 with a grade of C or better and PH113
Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Dynamical Systems 3R-3L-4C F,W,S Prereq: ECE204 and MA211
Review of matrix and differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical and mechanical systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C W,S Prereq: MA 211
A course designed for engineers (other than electrical or computer) covering analysis of passive circuits, introduction to op-amps, instrumentation, sinusoidal steady-state, a-c power, and induction motors. EE and CPE majors may not take this course.

ECE 207 Electrical Engineering 3R-3L-4C F,W Prereq: ES 203
A course designed for engineers (other than electrical or computer) covering AC power, three-phase systems, magnetic circuits, transformers, machines, strain gauges, RTDs and thermocouples, noise and shielding, and feedback systems. Integral laboratory. EE or CPE majors may not take this course.

ECE 230 Introduction to Microcontrollers 3R-3L-4C F,W Prereq: ECE130, CSSE120
Development of embedded systems with microcontrollers. Microcontroller architecture, instruction set, programmer's model, hardware modules, and assembly language programming. Data representation and

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- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
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- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

storage. Memory management. The C programming language, data structures and programming styles. Input and output devices. Data communications. Sensors and actuators. Real-time event measurement, generation and control. Interrupt generation and processing. Labs and a term project.

ECE 250 Electronic Device Modeling 3R-3L-4C F,W,S Prereq: ECE 204, MA 211

Modeling, analysis, and simulation of electronic circuits that contain two-terminal and three-terminal semiconductor devices. Large-signal, biasing, and small-signal analysis models. Introduction to wave shaping circuits, switching circuits, and amplifiers. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Prereq: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,S Prereq: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Integral laboratory.

ECE 320 Linear Control Systems 3R-3L-4C W,S Prereq: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C W,S Prereq: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C F,S Prereq: CSSE 232

Pipelining, memory hierarchy, peripherals, parallel processing, cost-performance tradeoffs, and a review of new topics in the areas of computer architecture or parallel processing. Computer use, memos, and discussion of current events.

ECE 333 Digital Systems 3R-3L-4C F,S Prereq: ECE 130, ECE 205, ECE 250

Capabilities and limitations of digital CMOS logic devices. Design and evaluation of combinational and sequential logic circuits using Programmable Logic Devices. System integration with multiple components (FPGA, discrete components). CAD tools for design entry, timing simulation, and mapping to target devices. Troubleshooting using laboratory instrumentation. Laboratory notebooks. Informal reports. Integral laboratory.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Prereq: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Prereq: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 343 High-Speed Digital Design 3R-3L-4C F,S Prereq: ECE 300 and Computer Engineering Major

Signal path modeling through connecting lengths of transmission lines with lumped element models of discontinuities. Circuit parameters from geometries and material properties for resistance, capacitance, inductance and transmission line segments. Lossless and lossy transmission line circuit modeling. High-frequency and high-speed behavior of passive components. Frequency spectrum of digital signals. Digital device

driver and receiver modeling. Transmission line impedance discontinuity and termination techniques. Electric and magnetic field coupling mechanisms for capacitive and inductive crosstalk. Ground noise, power plane noise and resonance. Signal and power integrity issues in high-speed digital systems at both the printed-circuit board and chip levels.

ECE 351 Analog Electronics 3R-3L-4C W,S Pre:req ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal properties of op-amps. Integral laboratory.

ECE 362 Principles of Design 3R-0L-3C F,S

Prereq for EE: ECE160, ECE250, ECE300, ECE340

Prereq for CPE: ECE160, ECE250, ECE300

Prereq for CS and SE majors: CSSE 374

Prereq for ME majors: EM 103, ES 205, and ECE 207

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3R-1L-4C F,S Prereq: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, and wind technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C W,S Prereq: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C W,S Prereq: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

ECE 410 Communication Networks 4R-0L-4C S Prereq: Senior standing or consent of instructor

Layered architectures. Circuit and packet switching. ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Reliable message transport, internetworking.

ECE 412 Software Defined Radio 4R-0L-4C Prereq: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front-end, and clock-jitter of the A/D. As a course project students will design and simulate a complete software-defined radio.

ECE 414 Wireless Systems 4R-0L-4C W Prereq: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Prereq: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with CHE 405, EP 410, and ME 416.

ECE 418 Fiber Optic Systems 4R-0L-4C S Prereq: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing

systems, and optical networks. Topics include basic architectures, component overview, system design, and expected degradations along with mitigation techniques. An oral presentation of a technical paper is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Prereq: ECE 320 or ME 406

Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prereq: ECE 320 or ME 406, Programming proficiency

This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Prereq: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Prereq: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Prereq: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F,W Prereq: ECE 362

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W,S

Prereq for EE: ECE310, ECE320 ECE333, ECE341, ECE351, ECE370 or ECE371, ECE380, ECE460

Prereq for CPE: CSSE332, ECE331, ECE332, ECE333, ECE342, ECE351, ECE380, ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W,S Prereq: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Prereq: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Prereq: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Prereq: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Prereq: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/PH 437 Introduction to Image Processing 3R-3L-4C Prereq: MA 212 and Junior standing

Basic techniques of image processing. Discrete and continuous two-dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory. Same as PH 437.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Prereq: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Prereq: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Prereq: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor

Special design or research projects.

UNDERGRADUATE-GRADUATE COURSES

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Prereq: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Prereq: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor

Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ME 519, EP 511, and CHE 519.

ECE530 Advanced Microcomputers 3R-3L-4C S Prereq: Graduate standing and ECE 331 or ECE 230; or ECE 331 or ECE 230 with a grade of B or better; or consent of instructor

32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software debugging tools. Integral laboratory.

ECE534 Advanced Signal and Power Integrity 4R-0L-4C W Prereq: Graduate Standing and ECE341, ECE342, or ECE343; or ECE341, ECE342, or ECE343 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal and power integrity modeling and measurement in high-speed digital systems at IC, PCB, and chassis levels. High-frequency behavior of passive components and packages. Behavior and SPICE models of drivers and receivers. Lossy transmission lines and discontinuity characterization. Mixedmode s-parameters and other network parameters. Frequency and time-domain modeling of capacitive and inductive crosstalk. Differential signaling techniques; timing conventions. Synchronization. Signal equalization. Power plane noise and resonance. High-speed PCB design guidelines. Measurement techniques including time-domain reflectometry, vector network analyzer and impedance analyzer. PCB simulation. Full-wave simulations.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Prereq: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of instructor

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C W Prereq: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Wave-guiding structures, microwave network analysis, scattering parameters, Z, Y and ABCD parameters, passive devices and components, design, fabrication, simulation and measurement of microwave devices and components, matching strategies, multi-conductor transmission lines and crosstalk.

ECE542 Advanced Electromagnetics 4R-0L-4C F Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, EM field theorems, potential functions, power and energy, material properties, wave propagation, reflection and transmission, radiation, scattering, Green's functions, metamaterials and metamaterial-inspired structures, modeling & simulation, measurement technique.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Prereq: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Prereq: Graduate standing and ECE351 and ECE380, or ECE351 and ECE380 with a grade of B or better in both courses, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C S Prereq: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C S Prereq: Graduate standing and ECE351, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Analog signal processing techniques using operational amplifiers. A/D and D/A converters. Protection from electric shock. Measurement of biological potential waveforms (ECG, EMG, EEG, ENG, EOG, ERG). Ultrasound techniques and instrumentation. X-ray CAT techniques. No laboratory, but

many in-class demonstrations and emphasis on circuit simulation.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C S Prereq: Graduate standing and ECE 351; or ECE 351 with a grade of B or better; or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE 557 Analog Test and Product Engineering 3R-3L-4C F Prereq: Graduate standing and ECE 300 and ECE 351; or ECE 300 and ECE351 with grades of B or better in both courses; or consent of instructor

Fundamental skills necessary to be an industrial integrated circuit test engineer or product engineer. Includes the economics associated with testing, impact of fabrication variation on devices, instrumentation associated with industrial testing, turning a data sheet into a test plan, industrial testing techniques for analog circuits, trade-offs between test time and test accuracy, statistical analysis of the data and statistical process control, the use of device interface boards necessary to control device loading for different tests. Integral labs with an industrial grade automatic tester (ATE).

ECE580 Digital Signal Processing 4R-0L-4C W Prereq: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Prereq: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE 582/PH 537 Advanced Image Processing 3R-3L-4C Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as PH 537.

ECE 583 Pattern Recognition 3R-3L-4C S Prereq: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 584 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and ECE300, or ECE300 with a grade of B or better, or consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as BE541.

ECE 597 Special Topics in Electrical Engineering 4C Prereq: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C Arranged

Thesis topic selected in consultation with adviser. Graduate students only.



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Engineering Management

Professors Andrijcic, Downing, Kline, Schumacher and Stamper

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4CPre: Junior, Senior, or consent of instructor

Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC Pre: MG 461 or consent of instructor

Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC Pre: MG 462 or consent of instructor

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT511 Graduate Seminar I 1R-0L-1C F

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT512 Graduate Seminar II 1R-0L-1C W

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT513 Graduate Seminar III 1R-0L-1C S

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT514 Graduate Seminar IV 1R-0L-1C Summer

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT520 Accounting for Technical Managers 4R-0L-4C Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership, Change and Organizational Culture 4R-0L-4C Management

Review of fundamental activities (planning, organizing, leading, controlling) related to the management of organizations. The concepts and techniques for maximizing the effectiveness of human resources in the achievement of organizational and project goals are emphasized. Topics include communication, team process, motivation, selection, development, and appraisal. Special focus is given to the management of human resources in a technical environment.

EMGT523 Marketing in New Product Development 4R-0L-4C Management

A study and overview of the components of marketing principles and how those mesh with management in a technical environment. Topics will include activities associated with product, price, promotion, and distribution and how these impact the technical manager from idea generation through delivery to and service for the customer.

EMGT524 Production/Operations Management 4R-0L-4C Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-0L-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-0L-4C

This course introduces the concepts of innovation types (radical, incremental, disruptive) and patterns of

technology evolution. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy use, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, expert judgment (Delphi), road-mapping and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-0L-4C Technical or Management

Addresses the major issues and techniques of project management, including team building, project evaluation and selection, scheduling techniques, quality management, development of negotiation and conflict management skills. Also examines project management success factors. Uses a large scenario planning exercise and several case studies to illustrate course content. Can be used as part of the technical or management core.

EMGT531 Economics for Technical Managers 4R-0L-4C Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C Management

The core of this course is the presentation of the Constructivist theory of communication and its application. Students are exposed to ethnographic interview methods and the concept of culture shock using the BAFA role-play simulation. Discussion of organizational culture includes a review of publications on this topic, the impact of culture on organizations, as well as strategies for change. May be used as a management core class.

**EMGT534 Management Science 4R-0L-4C F (even years) Prereq: Senior or graduate standing
Technical or Management**

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-0L-4C Management

Reviews the strategy literature and the issues surrounding strategy implementation in the context of organizational change. Includes a team project that explores the strategic implications of globalization for specific industries during the next 10 years and the construction of scenarios as a tool for understanding and communication. Individual students will develop and evaluate strategy for a specific organization within the scenarios developed in the team project.

EMGT540 Fundamentals of Engineering Management 4R-0L-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

**EMGT 551 Intellectual Property for Engineers and Scientists 4R-0L-4C Technical or Management
Elective**

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-0L-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization. Cross-listed with EMGT 486.

EMGT587 Systems Engineering 4R-0L-4C Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Prereq: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.



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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Engineering Mechanics

All courses in the engineering mechanics area are the responsibility of the Civil and Mechanical Engineering Departments.

EM 101 Statics 2R-0L-2C F Prereq: None

Covers static force analysis. Introduces scalars and vectors with applications to the study of forces, moments, and couples. Stresses free body diagrams with engineering examples.

EM 103 Introduction to Design 1R-3L-2C S Prereq: None

Introduces the engineering design process including problem definition, analysis, alternate solutions, specifications of final solution, and techniques of oral and written communications. Stresses the importance of teamwork through group design efforts.

EM 104 Graphical Communications 1R-2L-2C F Prereq: None

Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication.

EM 120 Engineering Statics 4R-0L-4C F,S Prereq: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, shear and bending moment diagrams, friction, and area moments of inertia. Emphasizes free-body diagrams.

EM 121 Statics and Mechanics of Materials I 4R-0L-4C F,S Prereq: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, and strength and elastic deflection of engineering materials due to loads applied axially. Emphasizes free-body diagrams.

EM 202 Dynamics 4R-0L-4C F Prereq: MA 112 and EM 120 or PH 111

Kinematics and kinetics of particles in space and rigid bodies in plane motion. Applications of the principles of Newton's laws, work-energy, impulse-momentum, and conservation laws to solutions of simple two-dimensional dynamics problems.

EM 203 Mechanics of Materials 4R-0L-4C F,W Prereq: EM 120

Strength and elastic deflection of engineering materials due to loads applied axially, in torsion, in bending, and in shear. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 204 Statics and Mechanics of Materials II 4R-0L-4C F,S Prereq: EM 121

Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 301 Fluid Mechanics 4R-0L-4C S Prereq: EM 202

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

*EM403 Advanced Mechanics of Materials 4R-0L-4C S Prereq: EM 203 or EM 204

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

EM 406 Vibration Analysis 4R-0L-4C F Prereq: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

UNDERGRADUATE-GRADUATE COURSES

***EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Prereq: ME401 or consent of instructor**

Course may be repeated for different topics in fluid mechanics.

***EM 502 Advanced Dynamics 4R-0L-4C Prereq: ES 205**

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

***EM 503 Advanced Vibration Analysis 4R-0L-4C W Prereq: EM 406**

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.

***EM 505 Theory of Elasticity 4R-0L-4C Prereq: EM 203 or EM 204**

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

***EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Prereq: EM 403 and MA 330**

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.

*May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Letfullin, McInerney, Moloney, Siahmakoun, Sirohi, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W Prereq: PH113
Scaling laws in small systems; electronics and photonics devices and systems, basics of quantum mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures ,carbon nanotubes, Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, Nanophotonics in metals and semiconductors, surface lasmon resonance and applications, photonic bandgap crystals.

EP 290 Directed Study Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S Prereq: EP280
Scaling laws in small systems; mechanical, biological, fluidics, and thermal systems. Basics of quantum mechanics, nanomaterials and nanofabrication. Nanomechanics: cantilever oscillation, atomic-force microscope (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors. Nanoscale heat: conduction, convection, and radiation. Basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise. Cross-listed with EP 506.

EP 408 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor
Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing
Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410 or equivalent course
Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-

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- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

listed with ECE 419, and CHE 419.

EP 415 Engineering Physics Projects I 4C S Prereq: RH330 and consent of the instructor

Team-oriented and/or independent design project work on selected topics in any engineering discipline but related to concepts to strengthen both the application and physics and engineering, design of project, building of prototype, experiments to test components and systems, and market analysis. Cross-listed with OE415.

EP 416 Engineering Physics Projects II 4C F Prereq: Consent of the instructor

Follow up course to EP415. To be taken as a sequence from the same department where EP415 was taken. Cross-listed with OE 416.

EP 417 Engineering Physics Projects III 2R-6L-4C W Prereq: Consent of the instructor

Follow up course to EP416. To be taken as a sequence from the same department where EP415 and EP416 were taken. Cross-listed with OE 417.

EP 470 Special Topics in Engineering Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 406.

EP 508 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.

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News

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Geology

GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Prereq: CHEM 111
Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.

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Admissions

Academics

Student Life

News

Calendars

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Athletics

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Mathematics

Professors Broughton, K. Bryan, Butske, Carlisle, Eichholz, Evans, Finn, Green, Graves, Grimaldi, Holden, A. Holder, L. Holder, Inlow, Isaia, Langley, Leader, McSweeney, Rader, Rickert, Selby, and Shibberu.

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Prereq: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.
A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen. Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

MA 111 Calculus I 5R-0L-5C F,W
Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

MA 112 Calculus II 5R-0L-5C F,W,S Prereq: MA111
Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

MA 113 Calculus III 5R-0L-5C F,W,S Prereq: MA112
Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

MA 190 Contemporary Mathematical Problems 2R-0L-2C S Co-requisite: MA113
A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and applications, famous problems, and outstanding problems of great significance.

MA 200 Career Preparation 1R-0L-1C W,S
This course is for mathematics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200 and PH200.

MA 211 Differential Equations 4R-0L-4C F,W, S Prereq: MA113
First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

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Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

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Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F,W,S Prereq: MA113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F,W,S Prereq: MA112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Prereq: MA112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Prereq: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged Prereq: CSSE220 or CSSE221, and MA212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W (odd years) Prereq: MA113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F Prereq: MA113

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F Prereq: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Prereq: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C S Prereq: MA211, MA212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary value problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three

dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Prereq: MA211, MA212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA 342 Computational Modeling 4R-0L-4C S Prereq: MA212 and one of CHE310, CE310 ,MA332 or ME323

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 348 Continuous Optimization 4R-0L-4C S (even years) Prereq: MA 212

Optimization of nonlinear functions of real variables: algorithms for univariate optimization; Golden section, parabolic interpolation, hybrid methods; Newton's Method and variations for multivariate functions; conjugate gradients and quasi-Newton methods; line search strategies; penalty functions for constrained optimization; modeling and applications of optimization.

MA 351-6 Problem Solving Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Prereq: MA275 and MA113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Prereq: MA212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Prereq: MA212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Pretrw: MA212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Prereq: MA275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Prereq: MA275

An introduction to Group Theory. Topics include: matrix groups, groups of integers modulo a natural number, symmetric and dihedral groups, homomorphisms, subgroups, cosets, quotient groups and group actions. Applications, possibly including games and puzzles, cryptography, and coding theory. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Prereq: Consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F,W,S Prereq: MA113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C F Prereq: MA381

This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the entral Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Prereq: MA223 or MA382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Prereq: MA223 or MA382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary.

MA 386 Statistical Programming 4R-0L-4C Prereq: previous programming course and either MA 23 or MA382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Prereq: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 390 Topics in the Mathematics of Engineering 1-2C Arranged Prereq:consent of instructor

A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

MA 421 Tensor Calculus and Riemannian Geometry 4R-0L-4C Arranged Prereq: MA330

An introduction to the calculus of tensor fields and the local geometry of manifolds.Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

MA 423 Topics in Geometry 4R-0L-4C Arranged Prereq: MA371 or MA373 or consent of instructor

An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C Arranged Prereq: Instructor permission

A topics course in the general area of continuous applied mathematics. Topics may

include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C Arranged Prereq: MA330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to “direct methods.” Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Prereq: MA212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C Arranged Prereq: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 435 Finite Difference Methods 4R-0L-4C W Prereq: MA332 or MA371 or MA373 or MA433

An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Prereq: MA330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green's function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Prereq: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Prereq: MA212 and one of MA371 or MA373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development “from the ground up.”

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Prereq: MA223 or MA381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Prereq: MA375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F,W,S Prereq: Consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C Arranged Prereq: Instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C Arranged Prereq: MA366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C Arranged Prereq: MA366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C Arranged Prereq: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Prereq: MA371 or MA373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Prereq: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C Arranged Prereq: MA375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Prereq: MA375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Prereq: MA375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C Arranged Prereq: MA 378 or MA375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Prereq: CSSE220 and MA275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C Arranged Prereq: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Prereq: MA382, or MA381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Prereq: MA223 or MA382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Prereq: MA212 and either MA223 or MA382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Prereq: MA223 or MA382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics Variable credit Prereq: Consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Prereq: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Prereq: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F,W Prereq: MA492 or permission of the instructor

MA 494 Senior Project III 2C W,S Prereq: MA493

Participation in sponsored projects or problems with a substantial mathematical and/or computational content. Students typically work in teams of at most 3, with appropriate faculty supervision. Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of Senior Project must be completed in a form acceptable to the sponsor and the advisor.

MA 495 Research Project in Mathematics Variable credit Prereq: Consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Prereq: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Prereq: MA496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Prereq: MA497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research

paper and public presentation to department are required.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Prereq: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C Arranged Pre: MA381

Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C Arranged Prereq: MA223 or MA381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Prereq: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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Mechanical Engineering

Professors Adams, Bernal, Brackin, Burchett, Chambers, Cornwell, Cunningham, Fine, Fisher, Gibson, Haan, Jones, Kawano, Layton, Lui, McCormack, Mayhew, Mech, Mirth, Moorhead, Moseley, Olson, Onyancha, Purdy, Richards, Sanders, Stamper, Stienstra, and White.

ME 123 Computer Applications I 4R-0L-4C W,S Prereq: None

Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion (Working Model), presentation software (Powerpoint, HTML), and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S

Selected student design projects. May include testing and/or computer aided design.

ME 201 Thermodynamics I 4R-0L-4C F Prereq: MA 112

Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: ME 292
Sophomore class standing

Selected student design projects. May include testing and/or computer aided design.

ME 301 Thermodynamics II 4R-0L-4C F,W Prereq: ES 202 or ME 201

Applies property and component background to the analysis of various power and refrigeration cycles. Presents gas and gas-vapor mixtures, psychrometric processes, and combustion. Introduces compressible flow.

ME 302 Heat Transfer 4R-0L-4C S,F Prereq: MA 211 and ES 202 or CHE 301 or EM 301

Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Prereq: ES 202

Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Prereq: EM 104

This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Prereq: ME 328

An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Prereq: ES 205, MA 223

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Computer Applications II 1R-3L-2C W,S Prereq: ME 123, or CSSE 120, MA 212

Introduction to structured programming and applied numerical methods in scientific computing. The course uses applied problems in engineering and mathematics to introduce numerical methods such as numerical interpolation, finite differencing, integration, root finding, and linear algebraic system solutions. Matlab is taught as a vehicle for solving the problems numerically in a structured high speed environment.

ME 328 Materials Engineering 4R-0L-4C W Prereq: CHEM 111

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Prereq: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

***ME 401 Foundations of Fluid Mechanics 3R-3L-4C Prereq: ES 202 or EM 301, MA 212**

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective*

***ME 402 Advanced Heat Transfer 4R-0L-4C Prereq: ME 302**

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 403 Kinematics of Machinery 4R-0L-4C Prereq: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

***ME 405 Theoretical Aerodynamics 4R-0L-4C F Prereq: ES 202**

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 406 Control Systems 3R-3L-4C F Prereq: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Prereq: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are

taken when available.

ME 408 Renewable Energy 4R-0L-4C Prereq: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C F Prereq: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Prereq: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Prereq: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Prereq: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 410, ECE 416, and CHE 405.

***ME 417 Advanced Materials Engineering 4R-0L-4C Prereq: ME 328 and EM 203 or EM 204**

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ECE 466, CHE 420, and CE 420.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Prereq: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

***ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Prereq: EM204**

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Prereq: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team

design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Prereq: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Prereq: ES 205 or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

***ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 430 Mechatronic Systems 3R-3L-4C F,W Prereq: ME 323 or CSSE 220 or ECE 230

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

***ME 435 Robotics Engineering 3R-3L-4C S Prereq: ME 430 and Senior class standing**

Interdisciplinary course in engineering systems applied to computer controlled automata. Topics include kinematics, control, operation, sensing, and design as applied to various types of industrial and other robots and programmable manipulators. A related project is required.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 450 Combustion 4R-0L-4C Prereq: ME 301**

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises.

**May be used to satisfy Mechanical Engineering requirement for an advaced technical elective.*

ME 461 Aircraft Design 4R-0L-4C W Prereq: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams.

ME 462 Thermal Design 4R-0L-4C W,S Prereq: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Engineering Design Processes and Methodology 2R-3L-3C F,S Prereq: 3rd qtr junior standing

Design of multi-component systems with consideration of societal and economic factors. Useful design techniques (such as modeling, CPM, optimization, probabilistic approaches, etc.) and factors influencing design (such as human factors, products liability, ethics, safety, etc.) are presented and discussed. Laboratory assignments emphasize case studies. (Students completing ME470 may not receive credit for EMGT 461.)

ME 471 Capstone Design I 1R-6L-3C W Prereq: ME 470, ME 480

Design projects with industry. Students work in teams with three or four members on design projects furnished from external clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in oral presentations and Interim Written Reports which are submitted to the clients.

ME 472 Capstone Design II 1R-6L-3C S Prereq: ME 471

This course is a continuation of ME 471. The student teams continue their design solutions to a general problem furnished by an external client. Continuous and regular communication with the outside clients is expected, as well as with the faculty advisors. During these ten weeks the teams continue refining their solutions, complete the detail design, make oral presentations of the final design, and complete and submit the Final Written Report.

ME 480 Machine Component Design 4R-0L-4C S & F Prereq: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Completion of freshman and sophomore course requirements and approval of adviser and course instructor

Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Senior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged
Topics of current interests in mechanical engineering.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

***ME 501 Advanced Thermodynamics 4R-0L-4C F Prereq: ME 301 or equivalent**

Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Prereq: ME 302**

Course may be repeated for different heat transfer topics.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 503 Viscous Fluid Flow 4R-0L-4C Prereq: ME 401**

Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Prereq: ES 205, MA 212**

Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 506 Advanced Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor**

Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 507 Applied Nonlinear Control Systems 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor**

Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liaqunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 510 Gas Dynamics 4R-0L-4C F Prereq: ES 202**

Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..*

***ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Prereq: ES 205 and ME 323**

Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 512 Light Weight Structures 4R-0L-4C S Prereq: MA 212 and EM 203 or EM 204**

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures, thin walled pressure vessels, introduction to elasticity.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 513 Environmental Noise 4R-0L-4C F Prereq: Senior class standing**

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

***ME 518 Advanced Kinematics 4R-0L-4C S Prereq: ME 403**

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Prereq: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Cross-listed with ECE 519, EP 511, and CHE 519.

***ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Prereq: EM 104 and Senior class standing**

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 522 Advanced Finite Element Analysis 4R-1L-4C S Prereq: ME 422**

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 526 Turbomachinery 4R-0L-4C Prereq: ES 205 or equivalent, or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency. Students enrolled in ME 526 must complete a design project including complexities not covered in ME 426. Students may not receive credit for both ME 426 and ME 526

***ME 527 Computational Fluid Dynamics 3R-3L-4C Prereq: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution. Students enrolled in ME527 must complete a design project not covered in ME 427. Students may not receive credit for both ME 427 and ME 527.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 536 Computational Intelligence in Control Engineering 4R-0L-4C Prereq: ME 406 or equivalent or consent of instructor**

Machine learning and adaptation applied to feedback control, guidance and navigation. Neural Networks for pattern recognition, modeling and control. Radial basis function model identification by recursive least squares. Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.
**May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 550 Combustion 4 R-0L-4C Prereq: ME 301**

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises. Students enrolled in ME 550 must complete a design project not covered in ME 450. Students may not receive credit for both ME 450 and ME 550
**May be used to satisfy Mechanical Engineering requirement for an advaced technical elective.*

***ME 590 Thesis Research F,W,S**

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.
** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S**

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..*



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MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Prereq: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Leaders' Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Leaders' Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

JUNIOR YEAR Advanced Course

MS 301: Adaptive Team Leadership 3R-3L-4C F Prereq: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 challenges cadets to study, practice, and evaluate adaptive leadership skills as they are presented with challenging scenarios related to squad tactical operations. Cadets receive systematic and specific feedback on their leadership attributes and actions. Based on such feedback, as well as their own self-evaluations, cadets continue to develop their leadership and critical thinking abilities. The focus is developing cadets' tactical leadership abilities to enable them to succeed at ROTC's summer Leadership Development and Assessment Course (LDAC).

MS 302: Leadership Under Fire 3R-3L-4C W Prereq: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when under fire are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Leader Development and Assessment Course (LDAC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Prereq: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for LDAC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

**Overview of LDAC: Leader Development and Assessment Course
Summer Term Only**

LDAC/Warrior Forge is the crucible of the Army ROTC Program. As such, Cadet Command must provide the best professional training and evaluation possible for all cadets. The primary focus at LDAC is to evaluate each cadet's officer potential in a collective environment. The secondary purpose of LDAC is to validate specific skills taught on campus and to impart selective individual and collective common skills. LDAC represents the only opportunity for this command to assemble cadets from disparate schools into an environment with common operational conditions.

SENIOR YEAR- Advanced Course

MS 401: Developing Adaptive Leaders 3R-3L-4C F Prereq: MS 303

MS 401 develops cadet proficiency in planning, executing, and assessing complex operations, functioning as a member of a staff, and providing performance feedback to subordinates. Cadets assess risk, make ethical decisions, and lead fellow ROTC cadets. Lessons on military justice and personnel processes prepare cadets to make the transition to Army officers. Cadets analyze, evaluate, and instruct cadets at lower levels. Both their

classroom and battalion leadership experiences are designed to prepare cadets for their first unit of assignment. They identify responsibilities of key staff, coordinate staff roles, and use situational opportunities to teach, train, and develop subordinates.

MS 402: Leadership in a Complex World 3R-3L-4C W Prereq: MS 401

MS 402 explores the dynamics of leading in the complex situations of current military operations in the COE. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. They also explore aspects of interacting with nongovernmental organizations, civilians on the battlefield, and host nation support. The course places significant emphasis on preparing cadets for their first unit of assignment. It uses case studies, scenarios, and What Now, Lieutenant? exercises to prepare cadets to face the complex ethical and practical demands of leading as commissioned officers in the United States Army.

MS 403: Leadership in a Complex World II 3R-3L-4C S Prereq: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Prereq: Permission of instructor

Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems.

OE 395 Optical Instrumentation 3R-3L-4C Arranged Prereq: OE 280 and PH 292

Radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; signal conditioning and noise; CCD arrays; optical instruments; color; selected experiments on the application of optical instruments.

OE 415 Optical Engineering Design I 2R-6L-4C S Prereq: OE 295 Coreq: RH330 or consent of the instructor

Principles of design. Codes of ethics appropriate to optical engineers. Case studies related to optical engineering professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415.

OE 416 Optical Engineering Design II 2R-6L-4C F Prereq: OE 415

Design project using formal design process; system-level design. Students work in teams to complete the first phase of the design. Teams translate customer needs to design specifications. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE 417 Optical Engineering Design III 2R-6L-4C W Prereq: OE416

Continuation of OE416 design project. Delivery of a functional prototype product. Complete product development documentation including a technical report, design documents, product design specification, drawings, acceptance test document, project plan. Oral presentation. Cross-listed with EP 417.

OE 435 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 435.

OE 450 Laser Systems and Applications 3R-3L-4C S Prereq: PH 292 and MA 212 or JR standing or consent of instructor

Laser safety; Gaussian beam propagation; beam quality; optical resonators; longitudinal and transverse modes; stability, stimulated emission; population inversion; rate equations; gain and threshold; Q-switching and mode-locking; types of laser systems; laser applications.

OE 470 Special Topics in Optical Engineering 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in optics.

OE 480 Lens Design and Aberrations 4R-0L-4C F Prereq: OE 280 Coreq: OE 360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Glass selection and introduction to computer-aided design. Classical lens design and design of imaging /non-imaging systems. Cross-listed with OE 580.

OE 485 Electro-Optics and Applications 3R-3L-4C W Prereq: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Cross-listed with OE 595.

OE 490 Directed Research Credit arranged Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3R-3L-4C F Prereq: OE393, ECE310 or graduate standing or consent of the instructor

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and

components: multiplexers, filters, common network topologies. Soliton propagation. Relevant laboratories

OE 495 Optical Metrology 3R-3L-4C F Prereq: PH 292 or SR/GR standing or consent of instructor and Co-Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); Review of interference and coherence; fringe visibility; third order aberrations; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Cross-listed with 595.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Prereq: OE 295, PH 292, PH 316 or SR/GR standing or consent of instructor

Classical optics; exact ray tracing; aberrations, interference, polarization, spatial and temporal coherence; lasers and Gaussian beam propagation; diffraction; optical sources and detectors; selected applications of optics.

OE 535 Biomedical Optics 3.5R-1.5L-4C Prereq: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 535.

OE 570 Special Topics in Optics 2 or 4C F,W,S Prereq: OE 295, PH 292, and PH 316

Lectures on special topics in optics such as: optical materials, optics of thin films and infrared optics.

OE 580 Lens Design and Aberrations 4R-0L-4C F Prereq: OE 280 Coreq: OE360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Glass selection and introduction to computer-aided design. Classical lens design and design of imaging/ non-imaging systems. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 480.

OE 585 Electro-Optics and Applications 3R-3L-4C W Prereq: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 485.

OE 592 Fourier Optics and Applications 3 R-3L-4C F Prereq: SR/GR standing or consent of instructor

Two-dimensional linear systems; diffraction theory (Fresnel & Fraunhofer); imaging properties of lenses; frequency analysis of optical imaging systems; spatial filtering; optical information processing; Vander-Lugt filters; wavefront reconstruction; holography; optical computing.

OE 593 Fundamentals of Optical Fiber Communications 3R-3L-4CS Prereq: OE393 or graduate standing or consent of the instructor

Evolution of fiber optics links and networks: information rate, evaluation of fiber optic systems, optical fiber transmission link. Digital transmission systems: point-to-point links, line coding, error correction. Analog systems: links, dynamic range, noise figure, bandwidth, carrier-to-noise, multi-channel transmission, cross talk. WDM concepts: operational principles, passive components, system considerations. Optical networks: network topologies, performance of linear bus, performance of star architecture, SONET, WDM networks, wavelength-routed networks, optical CDMA, ultra high capacity WDM networks, bit-interleaved optical TDM, time-slotted optical TDM.

Students enrolled in OE593 must do project work on a topic selected by the instructor.

OE 594 Guided-Wave Optics 3R-3L-4C S Prereq: OE 485 or SR/GR standing or consent of instructor


Theory of optical waveguides; waveguide modes; fabrication techniques; input and output coupling techniques; waveguide losses; waveguide gratings; electro-optic modulators; integrated optical detectors; applications of integrated optics.

OE 595 Optical Metrology 3R-3L-4C F Prereq: PH 292 or SR/GR standing or consent of instructor and Co-Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); Review of interference and coherence; fringe visibility; third order aberrations; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 495.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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PH 235 Many-Particle Physics 3.5R-1.5L-4C F Prereq: PH 111 or Coreq: EM 202; and Coreq: MA 112

Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Prereq: MA 111, and PH 111 or EM 120

Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Prereq: MA 111 and PH 111 or EM 120

Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Prereq: PH 113 and Coreq: MA 211

Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Prereq: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Prereq: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Prereq: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Prereq: PH 113

The wave equation; electromagnetic waves; phase and group velocities; complex refractive index; dispersion, interference; interferometers and applications, optical interferometry; coherence; polarized light; Jones vectors/matrices; production of polarized light; birefringence, Fraunhofer diffraction; diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Prereq: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Prereq: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S Arranged Prereq: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W Arranged Prereq: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Prereq: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Prereq: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Prereq: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Prereq: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication,

transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Prereq: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 330 Material Failure 3R-3L-4C W Pre:req PH 113

Physical principles of instrumentation used for material failure analysis, including light microscopy, electron microscopy, and spectroscopy. Laboratory includes experiments and case studies using these instruments.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Prereq: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schroedinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schroedinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Prereq: PH 113 and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Cross-listed with PH 505.

PH 407 Solid State Physics 4R-0L-4C S (even years) Prereq: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Prereq: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212, and JR/SR or Graduate standing

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory.

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Prereq: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Prereq: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Prereq: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Prereq: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must make arrangements with a physics and optical engineering faculty member for the research

project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Prereq: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Prereq: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Prereq: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Prereq: Consent of instructor

Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.



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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Robotics

ROBO 410 Robotics Capstone Design I 1R-6L-4C F
Pre for EE or CPE: ECE 362, and a co-requisite ME 430
Pre for ME: ME senior class standing, and co-requisites of ME 430 and ME 470
Pre for CS or SE: RH 330 and CSSE 374, and a co-requisite ME 430

ROBO 420 Robotics Capstone Design II 1R-6L-4C W
Pre: ROBO 410

ROBO 430 Robotics Capstone Design III 1R-6L-4C S
Pre: ROBO 420

Description: Interdisciplinary group robotics engineering project. This requires the carrying out, from inception to completion, of a robotics-related system development for an approved client. The focus for students from each major is on design appropriate to that major related to robotics. Teamwork activities are expected to involve coordination of multidisciplinary aspects of the project, team planning, leading, and reviewing of project progress versus risks. Engineering practices related to design include requirements and constraint analysis and management, design creation and documentation, prototyping, system construction and testing, following of engineering standards, and management of intellectual property. Technical completion and delivery to the client is expected.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry and Biochemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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Industry Partners

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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Sophomore Engineering

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 211 Differential Equations (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 212 Matrix Algebra & Systems of Differential Equations (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry and Biochemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,

- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,
- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Prereq: MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid & Thermal Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better

Conservation and accounting equations applied to fluid and thermal systems. Fluid and thermodynamic properties of pure substances. Open and closed systems hydrostatics. Dimensional analysis. Mechanical energy balance and pipe flow. Lift and drag.

ES 203 Electrical Systems 3R-3L-4C F,W,S Prereq: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Prereq: ES 201 with a grade of C or better Coreq: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Prereq: ES 202, ES 203 with a grade of C or better, OR ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Entrepreneurship Minor

Entrepreneurship Minor

Increasing globalization and the need for rapid implementation of innovations mean that the 21st Century engineers and scientists need to think like entrepreneurs. Everyone does not have to start a technology-based business, but understanding the business requirements of technology commercialization needs to be part of the preparation of technical leaders.

Engineering Management offers an entrepreneurship minor for undergraduates to consider. The program provides the basic tools for making new technology commercially successful.

The requirements of the undergraduate minor are 20 credits of the following:

Required Courses (8 credits)

- **EMGT 330 - Introduction to Engineering Management**
- **EMGT 532 - Technical Entrepreneurship**

OR

- **IA 453 - The Entrepreneur**

Choose three of the following courses (12 credits):

- **EMGT 520 - Accounting for Technical Managers**
- **EMGT 523 - Marketing in New Product Development**
- **EMGT 526 - Innovation Management & Forecasting**
- **EMGT 527 - Project Management**
- **SV 350 - Managerial Accounting**
- **SV 356 - Corporate Finance**
- **GS 350 - International Trade**
- **GS 351 - International Finance**

With approval from the Department Head of Engineering Management, course substitutions may be considered for better alignment with a student's professional aspirations. No more than one course may be transferred in to count toward the minor.

For more information contact the Engineering Management Department to discuss this opportunity: MSEM@rose-hulman.edu or 812-877-8822.

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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Applied Biology

The twenty-first century will see unparalleled advances in the biological sciences. Disciplines such as applied biology and biomedical engineering are burgeoning and will greatly impact the way we live in the future. The areas of functional genomics and proteomics will drive discoveries in molecular medicine, gene therapy and tissue engineering. Drug discovery will be facilitated by the elucidation of new target molecules and many pharmaceutical compounds will be produced using biological processes. Environmental management, remediation and restoration will also benefit from advances in applied biology. Biologists will be at the forefront of these advances and will drive the medical, agricultural, environmental and industrial applications of biological sciences.

The applied biology program will produce biologists with the chemistry, mathematics, and physics background needed to solve biotechnological problems in the coming decades. Those students wishing to strengthen their engineering skills can earn the area minor in biomedical engineering. Other students may choose to pursue a second major in Biochemistry and Molecular Biology. The program will prepare graduates for professional careers in government and industrial research laboratories, and in the biotechnology and health-related industries.

Those wishing to continue their studies in graduate or health professions programs will be exceptionally well qualified to do so.

Applied Biology Plan of Study

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
AB 110	Cell Structure and Function	4	AB 210	Mendelian & Molecular Genetics	4
CHEM 111	General Chemistry	4			
MA 111	Calculus I	5	CHEM 251	Organic Chemistry I	3
CLSK 100	College & Life Skills	1	CHEM 251L	Organic Chemistry I Laboratory	1
	Total	14			
Winter Term			Winter Term		
AB 120	Comparative Anatomy & Physiology	4	PH 111	Physics I	4
			MA 212	Matrix Algebra and Systems of Differential Equations	4
CHEM 113	General Chemistry II	4		Total	16
MA 112	Calculus II	5			
BE 100	Problem Solving in the Biological Sciences and Engineering	4			
	Total	17			
Spring Term			Spring Term		
AB 130	Evolution and Diversity	4	AB 220	Prokaryotic Cell & Molecular Biology	4
CHEM 115	General Chemistry III	4	CHEM 252	Organic Chemistry II	3
MA 113	Calculus III	5	CHEM 252L	Organic Chemistry II Lab	1
RH 131	Rhetoric & Composition	4	PH 112	Physics II	4
	Total	17	RH 330	Technical and Professional Communication	4
				Total	16

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

<i>Spring Term</i>		<i>Credit</i>
AB 230	Eukaryotic Cell & Molecular Biology	4
CHEM 253	Organic Chemistry III	3
CHEM 253L	Organic Chemistry III Lab	1
PH 113	Physics III	4
MA 223	Engineering Statistics	4
Total		16

Junior Year

<i>Fall Term</i>		<i>Credit</i>
AB 320	Ecology	4
CHEM 330	Biochemistry	4
HSS	Elective	4
AB 399	Practice of Science	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
AB 330	Evolutionary Biology	4
AB 496	Senior Thesis Research I	2
AB	Elective	4
HSS	Elective	4
Total		14

<i>Spring Term</i>		<i>Credit</i>
AB 310	Plant Structure & Function	4
AB 497	Senior Thesis Research II	4
SV 304	Bioethics	4
HSS	Elective	4
Total		16

Senior Year

<i>Fall Term</i>		<i>Credit</i>
AB 498	Senior Thesis Research III	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16

<i>Winter Term</i>		<i>Credit</i>
AB 499	Senior Thesis Research IV	2
	Science/Technical Elective	4
AB	Elective	4
HSS	Elective	4
Total		14

<i>Spring Term</i>		<i>Credit</i>
AB	Elective	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
Total		16
Total credits required:		188

An AB science/technical elective is any Rose-Hulman course that has a prefix of AB, BE, CHEM, CHE, CE, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required AB courses	52 credits
AB electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	12 credits
Required MA, CHEM, PH	63 credits
Required CLSK	1 credit
Sci/Tech electives	12 credits
Required BE course	4 credits
Total	188 credits

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility. Two faculty are directly involved with this program: Dr. Mark Brandt, assistant professor of chemistry, is the program coordinator and is a biochemist, and Dr. Richard Anthony, associate professor of applied biology, is a molecular biologist. Many other faculty in both the chemistry and applied biology departments assist with this curriculum.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the

student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required Courses

			Elective Courses	
Course	Description	Hours	Choose 12 credits* from the following courses:	
CHEM 111, 113, 115	General Chemistry	12		
CHEM 251, 252, 253	Organic Chemistry	9		
CHEM 251L, 252L, 253L	Organic Chemistry	3	AB 330	Evolutionary Biology
	Lab		AB 421	Applied Microbiology
CHEM 330, 430, 433	Biochemistry	9	AB 431	Genomics and Proteomics
CHEM 361, 362			AB 441	Virology
or			AB 451	Cancer Biology
CHEM 360			AB 492	Directed Study in Applied Biology
and			CHEM 225	Analytical Chemistry
CHE 303, 304	Physical Chemistry	8	CHEM 291	Introduction to Research
AB 110, 120, 130	Biology	12	CHEM 331	Biochemistry II
AB 210	Genetics	4	CHEM 431	Biochemical Instrumentation
AB 220, 230	Molecular Biology	8	CHEM 451	Organic Structure Determination
AB 411	Genetic Engineering	4	CHEM 290	
Total		69	or	
			CHEM 490	Chemical Research
			PH 302	Biophysics

Total Credits for Second Major 81

*Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the AB electives listed, and 4 credits chosen from any AB or BE course.

STUDENTS WITH A MAJOR IN APPLIED BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above AB course (total: 29 hours required beyond Applied Biology major).

Applied Biology Area Minor

The Area Minor in Applied Biology is designed to allow students to enrich studies in their major area. Students wishing to apply another science, mathematics, or engineering discipline to investigate or solve problems in biological systems are encouraged to pursue the Area Minor in Applied Biology. With proper course selection, the Area Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Area Minor in Applied Biology has the following requirements.


1. All students must complete AB110 (Cell Structure and Function) or AB130 (Evolution and Diversity) and at least four more courses in applied biology (AB) or allied areas, above those courses already specifically required to fulfill the student's major.
 - a. At least three of the four electives must be AB courses.
 - b. At least three of the electives must be 200-level or above.Additional courses not listed in the approved allied areas can be considered on a case-by-case basis. See ABBE Department Head.
2. Students electing to pursue the Area Minor in Applied Biology must follow a plan of study that is approved by the Area Minor Advisor. Current advisor information and a form for the planning and approval of an area minor can be obtained from the ABBE Department secretary.
3. Allied area courses could include:
 - BE 310 Analysis of Physiological Systems I
 - BE 320 Analysis of Physiological Systems II

- BE/MA 482 Bioengineering Statistics
- BE 570 Introduction to Tissue Engineering
- CE 460 Introduction to Environmental Engineering
- CHE 545 Introduction to Biochemical Engineering
- CHEM 264 Environmental Chemistry
- CHEM 330 Survey of Biochemistry
- CHEM 430 Advanced Biochemistry
- PH 302 Biophysics
- SL 386 Human Evolution
- VA 373 Gender Issues

Biochemistry & Molecular Biology Area Minor

Completion of AB110, CHEM111, CHEM113 and CHEM115. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

- AB 210 Mendelian and Molecular Genetics
- AB 220 Prokaryotic Cell and Molecular Biology
- or
- AB 230 Eukaryotic Cell and Molecular Biology
- AB 411 Genetic Engineering
- or
- AB 431 Genomics and Proteomics
- CHEM Introduction to Organic Chemistry and
- 230 Biochemistry
- or
- CHEM Organic Chemistry I
- 251
- and
- CHEM 252 Organic Chemistry II
- CHEM 330 Biochemistry
- CHEM Advanced Biochemistry
- 430
- with
- CHEM 433 Biochemistry Laboratory



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Biochemistry Plan of Study

Freshman Year			Sophomore		
Fall Term			Year		
CHEM 111*	General Chemistry I	4	Fall Term		
MA 111	Calculus I	5	CHEM 251	Organic Chemistry I	3
AB 110	Cell Structure & Function	4	CHEM 251L	Organic Chemistry I Lab	1
CLSK 100	College & Life Skills	1	PH 113	Physics III	4
RH 131	Rhetoric and Composition	4	MA 212	Matrix Algebra and Systems	4
HSS	or			of Differential Equations	
	Elective		AB 210	Mendelian &	4
	Total	18		Molecular Genetics	
Winter Term				Total	16
CHEM 113*	General Chemistry II	4	Winter Term		
MA 112	Calculus II	5	CHEM 200	Career Preparation	1
PH 111	Physics I	4		(take in winter or spring)	
RH 131	Rhetoric and Composition	4	CHEM 252	Organic Chemistry II	3
HSS	or		CHEM 252L	Organic Chemistry II Lab	1
	Elective		CHEM 291	Intro to Undergraduate Research	4
	Total	17	MA 381	Introduction to Probability with Applications to Statistics	4
Spring Term			AB 220	Prokaryotic Cell & Molecular Biology	4
CHEM 115	General Chemistry III	4		Total	16 or 17
MA 113	Calculus III	5	Spring Term		
PH 112	Physics II	4			Credit
HSS	Elective	4			
	Total	17			

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Junior Year			CHEM 200	Career Preparation (take in winter or spring)	1
<i>Fall Term</i>			CHEM 253	Organic Chemistry III	3
CHEM 326	Bioanalytical Chemistry	4	CHEM 253L	Organic Chemistry III Lab	1
CHEM 330	Biochemistry I	4	CHEM 225	Analytical Chemistry	4
CHEM 361	**Physical Chemistry I	4	AB 230	Eukaryotic Cell & Mol. Biology	4
HSS	Elective	4			
Total		16	HSS	Elective	4
<i>Winter Term</i>			Total		16 or 17
CHEM 327	Advanced Analytical	4			
CHEM 362	**Physical Chemistry II	4			
CHEM 331	Biochemistry II	4			
CHEM 400	Chemical Communication I	1			
HSS	Elective	4			
Total		17	Senior Year		
<i>Spring Term</i>			<i>Fall Term</i>		<i>Credit</i>
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4	CHEM 441	Inorganic Chemistry I	4
CHEM 430	Advanced Biochemistry	4	CHEM 401	Chemical Communication II	1
CHEM 433	Biochemistry Lab	1	CHEM 490	Chemistry Research	1
HSS	Elective	4		##Advanced Chemistry or Biochemistry Elective	4
CHEM 490#	Research	1		Advanced Biology Elective	4
Total		14		Free Elective	4
				Total	18
			<i>Winter Term</i>		<i>Credit</i>
			CHEM 402	Chemical Communication III	1
			CHEM 490	Chemistry Research	1
			HSS	Elective	4
				##Advanced Biology, Chemistry, Biochem	4
				Free Elective	
				Total	14
			<i>Spring Term</i>		<i>Credit</i>
			CHEM 403	Chemical Communication IV	1
			CHEM 490	Chemistry Research	1
				HSS Elective	4
				Free Elective	4
				Free Elective	4
				Total	14
			Total credits required:		194

Notes: Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM111 General Chemistry I is an automatic substitution for the former **CHEM105 Engineering Chemistry I**.

CHEM113 General Chemistry II is an automatic substitution for the former **CHEM107 Engineering Chemistry II**.

*Subject to approval, **CHEM 112** may be substituted for **CHEM 111** and **CHEM 113**.

CHE 303, CHE 304 and **CHEM 360 may be substituted for **CHEM 361** and **CHEM 362**.

#Students must complete at least 3 credits of **CHEM 490** prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from **CHEM 290**.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits	Summary of minimum graduation requirements:		
General Chemistry	111, 113, 115	12			
Organic Chemistry	251, 252, 253	12			
Analytical Chemistry	225, 326, 327	12	Course or areas	Required Elective	Total

Physical Chemistry	361, 362, 363	12	Chemistry	78	8	86
Inorganic Chemistry	441	4	Physics	12	0	12
Biochemistry	330, 331, 430, 433	13	Mathematics	23	0	23
Research	291, 490	8	Biology	20	0	20
Chemical Communication	400, 401, 402, 403	4	Humanities and Social Sciences	4	32	36
Career Preparation	200	1	Electives	0	16	16
Electives		8	College and Life Skills	1	0	1
Total		86	Total	136	56	194


Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
*CHEM111	General Chemistry I	4
*CHEM113	General Chemistry II	4
*CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		32

*CHEM 105 and CHEM 107 can be substituted for CHEM111You may replace CHEM111, CHEM 113, and CHEM 115.

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	4
or CHEM253	Organic Chemistry III	
CHEM330	Biochemistry I	4
or CHEM361	Physical Chemistry I	
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

- be able to design and conduct experiments, making measurements from both living and non-living systems.
- be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- be able to function in multidisciplinary teams in different roles.
- be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- have the skills required for self-learning.
- be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Biomedical Engineering Plan of Study

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
AB 110	Cell Structure and Function	4	ES 201	Conservation & Accounting Principles	4
PH 111	Physics I	4			
MA 111	Calculus I	5	CHEM 111	General Chemistry I	4
CLSK 100	College & Life Skills	1	MA 211	Differential Equations	4
EM 104	Graphical Communication	2	ES 203	Electrical Systems	4
	Total	16		Total	16
Winter Term		Credit	Winter Term		Credit
AB 120	Comparative Anatomy & Physiology	4	ES 202	Fluid and Thermal Systems	3
PH 112	Physics II	4	ES 204	Mechanical Systems	3
MA 112	Calculus II	5	MA 212	Matrix Algebra and Systems of Differential Equations	4
BE 100	Problem Solving in the Biological Sciences and Engineering	4	CHEM 113	General Chemistry II	4
	Total	17	HSS	Elective	4
				Total	18
Spring Term		Credit	Spring Term		Credit
PH 113	Physics III	4	BE 201	Biomedical Measurements	4
RH 131	Rhetoric & Composition	4	AB 130	Evolution and Diversity	4
MA 113	Calculus III	5	ES 205	Analysis & Design of Engineering Systems	4
EM 121	Statics and Mechanics of Materials I	4			
	Total	17	MA 223	Engineering Statistics	4
				Total	16
Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
HSS	Elective	4	BE 410	Biomedical Engineering Design I	4
AB 205	Cellular Physiology	4			
RH 330	Technical and Professional	4	HSS	Elective	4

HSS	Communication			Free Elective	4
	or		BE	Area Elective	4
	Elective			Total	16
EM 204	Statics and	4	Winter Term		Credit
	Mechanics of Materials II		BE 420	Biomedical Engineering	4
	Total	16		Design II	
Winter Term		Credit	HSS	Elective	4
BE 310	Physiological Systems I	4		Free Elective	4
BE 331	Biomechanics	3	BE	Area Elective	4
BE 351	Biomedical Engineering Lab	2		Total	16
BE 361	Biomaterials	3	Spring Term		Credit
HSS	Elective	4	BE 430	Biomedical Engineering	2
	or			Design III	
RH 330	Technical and		HSS	Elective	4
	Professional			Free Elective	4
	Communication		BE	Area Elective	4
	Total	16		Total	14
Spring Term		Credit	Total credits required:		192
SV 304	Bioethics	4			
BE 320	Physiological Systems II	4			
BE 390	Principles of Biomedical	2			
	Engineering Design				
BE	Area	4			
	Total	14			

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the ABBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

Biomaterials Concentration

Course	Title
BE 417	Advanced Materials
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanincs
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both
**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

Biomedical Instrumentation Concentration

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols
BE 516	Introduction to MEMS

BE 435/535	Biomedical Optics
BE 555	Electrophysiology
ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

Biomechanics Concentration

Course	Title
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
BE 525	Biomedical Fluid Mechanics
BE 531	Biomechanics II
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopaedic Biomechanics
BE 550	Research Methods in Biomechanics
EM 403	Advanced Mechanics of Materials
ME 422	Finite Elements for Engineering Applications
ME 520	Computer-Aided Design and Manufacturing
ME 522	Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Area Minor

The biomedical engineering area minor is intended to provide a strong biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and the health care related fields.

In order to complete the requirements in the biomedical engineering area minor, a student must complete AB110 "Cell Structure and Function" and 16 credits from list shown below. At least three of the courses must have a BE prefix.

Biomedical Engineering Minor Electives

PH 302	4	Biophysics
AB 411	4>	Genetic Engineering
BE 310	4	Analysis of Physiological Systems I
BE 320	4	Analysis of Physiological Systems II
BE 331		Biomechanics
BE 340	4	Biomedical Instrumentation
BE 350	4	Biocontrol Systems
BE 351	2	Biomedical Engineering Lab *
BE 352	1	Biomechanics Lab *
BE 353	1	Biomaterials Lab *
BE 361	3	Biomaterials
BE 435/535	4	Biomedical Optics
BE 482	4	Bioengineering Statistics

BE 510	4	Biomedical Signal and Image Processing
BE 525	4	Biomedical Fluid Mechanics
BE 531	4	Biomechanics II
BE 534	4	Soft Tissue Mechanics
BE 539	4	Multiscale Biomechanics
BE 541	4	Medical Imaging
BE 543	4	Neuroprosthetics
BE 545	4	Orthopaedic Biomechanics
BE 550	4	Research Methods in Biomechanics
BE 555	4	Electrophysiology
BE 560	4	Tissue-Biomaterial Interactions
BE 570	4	Introduction to Tissue Engineering


*Students getting credit for BE351 cannot get credit for BE352 or BE353.

In addition to courses on the above list, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

Basic Engineering Courses

EM 121	Statics and Mechanics of Materials I
EM 204	Statics and Mechanics of Materials II
EM 301	Fluid Mechanics
ECE 130	Introduction to Logic Design
ECE 200	Circuits & Systems
ES 201	Conservation & Accounting Principles
ES 202	Fluid & Thermal Systems
ES 203	Electrical Systems
ES 204	Mechanical Systems
CHE 201	Conservation Principles and Balances
CHE 202	Basic Chemical Process Calculations
CHE 301	Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the Head of the Department of Applied Biology and Biomedical Engineering.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies



Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

- Our graduates will attain a promotion and/or responsibilities beyond their entry-level position, or progress toward the completion of an advanced degree.
- Our graduates will continue to develop professionally.
- Our graduates will collaborate professionally within or outside of their organizations at a regional, national and/or international level.
- Our graduates will participate in service to their professions and/or community organizations.

Student Outcomes

Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

11. A knowledge of contemporary issues

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year
(A1 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
RH 131	Rhetoric & Composition	4
MA 111	Calculus I	5
Total		16
Winter Term		Credit
CHEM 113	General Chemistry II*	4
PH 111	Physics I	4
HSS	Elective	4
MA 112	Calculus II	5
Total		17
Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Freshman Year
(A2 Schedule)

Fall Term		Credit
CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
RH 131	Rhetoric & Composition	4
MA 111	Calculus I	5
Total		16
Winter Term		Credit
CHEM 113	General Chemistry II*	4
PH 111	Physics I	4
HSS	Elective	4
MA 112	Calculus II	5
Total		17
Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2
MA 113	Calculus III	5
PH 112	Physics II	4
Total		17

Sophomore Year
(A1 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4
EM 101	Statics I	2
Total		14

Sophomore
Year
(A2 Schedule)

Fall Term		Credit
CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Lab	1
MA 211	Differential Equations	4
EM 101	Statics I	2

<i>Winter Term</i>			<i>Credit</i>			Total			14
CHE 202	Basic Chemical Process	4	<i>Winter Term</i>			<i>Credit</i>			
	Calculations		CHE 202	Basic Chemical Process	4				
CHEM 252	Organic Chemistry II	3		Calculations					
			CHEM 252	Organic Chemistry II	3				
CHEM 252L	Organic Chemistry II Lab	1							
MA 212	Matrix Algebra and Systems	4	CHEM 252L	Organic Chemistry II Lab	1				
	of Differential Equations		MA 212	Matrix Algebra and Systems	4				
HSS	Elective	4		of Differential Equations					
	Total	16	HSS	Elective	4				
<i>Spring Term</i>			<i>Credit</i>			Total			16
CHE 301	Fluid Mechanics	4	<i>Spring Term</i>			<i>Credit</i>			
CHE 303	Chemical Engineering	4	MA 223	Engineering Statistics I	4				
	Thermodynamics		CHEM 225	Analytical Chemistry I	4				
	Elective (Approved)	4	HSS	Elective	4				
HSS	Elective	4	CHE 315	Materials Science	4				
	Total	16		Total	16				

Junior
Year
(A1
Schedule)

<i>Fall Term</i>			<i>Credit</i>		
CHE 304	Multi-Component	4			
	Thermodynamics				
CHE 320	Fundamentals of Heat and Mass	4			
	Transfer				
CHE 315	Materials Science	4			
CHEM 225	Analytical Chemistry I	4			
	Total	16			
<i>Winter Term</i>			<i>Credit</i>		
CHE 321	Applications of Heat and Mass	4			
	Transfer				
CHEM 360	Intro Physical Chemistry	4			
MA 223	Engineering Statistics I	4			
RH 330	Technical and	4			
	Professional Communication				
	Total	16			
<i>Spring Term</i>			<i>Credit</i>		
CHE 404	Kinetics & Reactor Design	4			
CHE 411	Chemical Engineering Lab I	3			
ECE 206	Elements of	4			
	Electrical Engineering				
HSS	Elective	4			
	Total	15			

Senior Year
(A1 Schedule)

<i>Fall Term</i>			<i>Credit</i>		
CHE 409	Professional Practice	1			
CHE 412	Chemical Engineering Lab II	4			
CHE 416	Design I	4			
	Free Elective(Free)	4			
	Free Elective(CHE)	4			
	Total	17			
<i>Winter Term</i>			<i>Credit</i>		
CHE 413	Chemical Eng. Lab III	4			
CHE 417	Design II	4			
CHE 440	Process Control	4			
HSS	Elective	4			

Junior
Year
(A2
Schedule)

<i>Fall Term</i>			<i>Credit</i>		
CHE 301	Fluid Mechanics	4			
CHE 303	Chemical Engineering	4			
	Thermodynamics				
	Elective (Approved)	4			
RH 330	Technical and	4			
	Professional Communication				
	Total	16			
<i>Winter Term</i>			<i>Credit</i>		
CHE 304	Multi-Component	4			
	Thermodynamics				
CHE 320	Fundamentals of Heat and Mass	4			
	Transfer				
ECE 206	Elements of	4			
	Electrical Engineering				
HSS	Elective	4			
	Total	16			
<i>Spring Term</i>			<i>Credit</i>		
CHE 325	Applications of Heat and Mass	4			
	Transfer				
CHE 411	Chemical Engineering Lab I	3			
CHEM 360	Intro Physical Chemistry	4			
HSS	Elective	4			
	Total	15			

Senior Year
(A2 Schedule)

<i>Fall Term</i>			<i>Credit</i>		
CHE 404	Kinetics & Reactor Design	4			
CHE 409	Professional Practice	1			
CHE 412	Chemical Engineering Lab II	4			
CHE 416	Design I	4			
	Free Elective(Free)	4			

Total			16	Total			17
<i>Spring Term</i>			<i>Credit</i>	<i>Winter Term</i>			<i>Credit</i>
CHE 418	Design III		2	CHE 413	Chemical Eng. Lab III		4
HSS	Elective		4	CHE 417	Design II		4
HSS	Elective		4	CHE 440	Process Control		4
	Elective(Approved)		4	HSS	Elective		4
	Elective(CHE)		4	Total			16
Total			18	<i>Spring Term</i>			<i>Credit</i>
Total credits required:			194	CHE 418	Design III		2
				HSS	Elective		4
					Elective(CHE)		4
					Elective(CHE)		4
					Elective(Approved)		4
				Total			18
				Total credits required:			194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 405 Introduction to MEMS: Fabrication and Applications
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student’s academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Area Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 320 Fundamentals of Heat and Mass Transfer
- CHE 321 Applications of Heat and Mass Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Area Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- AB110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology
- or
- AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering
- AB421 - Applied Microbiology
- AB431 - Genomics and Proteomics
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary

AREA OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. Students may not count courses towards a concentration that also count towards another concentration or towards a minor, certificate, double major, or second degree. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)

- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 450 Air Pollution
- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy

Industrial and Process Engineering


Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT534 Management Science
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems



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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include applied biology, chemical engineering and mathematics.

Chemistry Plan of Study

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
CHEM 111*	General Chemistry	4	CHEM 251	Organic Chemistry I	3
MA 111	Calculus I	5			
AB 110**	Cell Structure and Function	4	CHEM 251L	Organic Chemistry I Lab	1
			PH 113	Physics III	4
CLSK 100	College & Life Skills	1	MA 212	Matrix Algebra and Systems	4
RH 131	Rhetoric and Composition	4		of Differential Equations	
	or			Free Elective	4
HSS	Elective			Total	16
	Total	18			
Winter Term			Winter Term		
CHEM 113*	General Chemistry II	4	CHEM 200	Career Preparation	1
MA 112	Calculus II	5		(take in winter or spring)	
PH 111	Physics I	4	CHEM 252	Organic Chemistry II	3
RH 131	Rhetoric and Composition	4			
	or		CHEM 252L	Organic Chemistry II Lab	1
HSS	Elective		CHEM 291	Intro to Undergraduate Research	4
	Total	17			
Spring Term			Spring Term		
CHEM 115	General Chemistry III	4	MA 381	Introduction to Probability	4
MA 113	Calculus III	5		with Applications to Statistics	
HSS	Elective	4		Free Elective	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

PH 112	Physics II	4		Total	16 or
	Total	17			17
			Spring Term		Credit
			CHEM 200	Career Preparation (take in winter or spring)	1
			CHEM 253	Organic Chemistry III	3
Junior Year					
Fall Term		Credit	CHEM 253L	Organic Chemistry III Lab	1
CHEM 326	Bioanalytical Chemistry	4	CHEM 225	Analytical Chemistry I	4
CHEM 361	***Physical Chemistry I	4	HSS	Elective	4
CHEM 330	Biochemistry I	4		Free Elective	4
HSS	Elective	4		Total	16 or
	Total	16			17
Winter Term		Credit			
CHEM 327	Advanced Analytical	4			
CHEM 362	***Physical Chemistry II	4			
CHEM 400	Chemical Communications I	1			
HSS	Elective	4	Senior Year		
	Free Elective	4	Fall Term		Credit
	Total	17	CHEM 441	Inorganic Chemistry I	4
			CHEM 401	Chemical Communications II	1
Spring Term		Credit	CHEM 490	Research	1
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4		Chemistry Elective	4
				Free Elective	4
CHEM 451	Organic Structure Determination	4		Total	14
			Winter Term		Credit
HSS	Elective	4	CHEM 442	Inorganic Chemistry II	4
	Free Elective	4	CHEM 402	Chemical Communications III	1
CHEM 490#	Research	1	CHEM 490	Research	1
	Total	17	HSS	Elective	4
				Chemistry Elective	4
				(400-level)###	
				Total	14
			Spring Term		Credit
			CHEM 403	Chemical Communications IV	1
			CHEM 490	Research	1
			HSS	Elective	4
				Free Elective	4
				Free Elective	4
				Total	14
			Total credits required: 193		

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM111 General Chemistry I is an automatic substitution for the former CHEM105 Engineering Chemistry I.

CHEM113 General Chemistry II is an automatic substitution for the former CHEM107 Engineering Chemistry II.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

AB120 or AB130 may be substituted for AB110 *CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits	Summary of minimum graduation requirements:
General Chemistry	111, 113, 115	12	

			Course or areas	Required	Elective	Total
Organic Chemistry	251, 252, 253	12	Chemistry	77	8	85
Analytical Chemistry	225, 326, 327	12	Physics	12	0	12
Physical Chemistry	361, 362, 363	12	Mathematics	23	0	23
Inorganic Chemistry	441, 442	4	Biology	4	0	4
Biochemistry	330	4	Humanities and Social	4	32	36
Organic Structure	451	4	Sciences			
Determination			Electives	0	32	32
Chemical Communication	400, 401, 402, 403	4	College and Life Skills	1	0	1
Research	291, 490	8	Total	121	76	193
Career Preparation	200	1				
Electives		8				
Total		85				

Area Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in applied biology or chemical engineering are different from those majoring in other disciplines.

Area Minor in Chemistry for Most Students

Course Number	Course Title	Credits
CHEM113	General Chemistry II	4
CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM252	Organic Chemistry II	4
	*Approved List of Chemistry Electives	4
Total		24

*Approved list of chemistry electives includeCHEM253, CHEM290 (up to two credit hours), CHEM291, or any 300 or 400 level chemistry courses.

Area Minor in Chemistry for Chemical Engineering and Applied Biology Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	4
CHEM253	Organic Chemistry III	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student's major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM111	General Chemistry I	4
CHEM113	General Chemistry II	4
CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHEM 465	Energy and the Environment	4
Total		32

Environmental Chemistry Minor for Chemical

Engineers and Applied Biology Majors
Environmental Certificate for Chemistry and
Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	4
CHEM253	Organic Chemistry III	4
or	Biochemistry	
CHEM330		
CHEM361	Physical Chemistry I	4
or	Chemical Engineering	
CHE303	Thermodynamics	
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE 465	Energy and the Environment	4
Total		24



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society's need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department's Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department’s Program Educational Objectives and Student Learning Outcomes*

Program Educational Objectives

- I. Graduates will demonstrate the ability to perform **essential engineering functions** in the design, management, or construction industry.
- II. Graduates will demonstrate the ability to **design/construct complex engineering systems** in the broad-based engineering industry.
- III. Graduates will demonstrate their potential for **technical leadership and management**.

Student Learning Outcomes

1. **Technical Core** - Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
2. **Experiments** - Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

- 3. **Engineering Problems** - Develop problem statements and solve well-defined engineering problems in four technical areas appropriate to civil engineering.
- 4. **Engineering Impact** - Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- 5. **Contemporary Issues** - Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.
- 6. **Design** - Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- 7. **Multidisciplinary** - Function effectively as a member of a multidisciplinary team.
- 8. **Professional/Ethical** - Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- 9. **Communication** - Organize and deliver effective verbal, written, and graphical communications.
- 10. **Engineering Tools** - Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.
- 11. **Life Long Learning** - Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- 12. **Leadership** - Apply leadership principles to direct the efforts of a small group.
- 13. **Service** - Use one's time and skills to benefit an individual or community without cost to the recipient.
- 14. **Project Management** - Explain key concepts in project management, and develop solutions to well-defined project management problems.
- 15. **Business and Public Administration** - Explain key concepts and processes used in business, public policy, and public administration.
- 16. **Cultural and Global Awareness** - Analyze and interpret cultural perspectives and social systems that define human characteristics.

* The civil engineering program uses the term "educational objective" to describe the expected accomplishments of our students in three to five years following graduation. The term "student learning outcome" is used to describe knowledge and skills at the time of graduation.

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Civil Engineering Plan of Study

Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	5	Fall Term		
PH 111	Physics I	4	MA 211	Differential Equations	4
RH 131	Rhetoric and Composition	4	CHEM 111	General Chemistry I	4
	or		EM 202	Dynamics	4
	Elective(HSS)			Elective(HSS)	4
CLSK 100	College & Life Skills	1	CE 201	Engineering Surveying II	2
EM 104	Graphical Communications	2		Total	18
	Total	16	Winter Term		
Winter Term			MA 212	Matrix Algebra and	4
MA 112	Calculus II	5		Systems	
PH 112	Physics II	4		of Differential Equations	
RH 131	Rhetoric and Composition	4	EM 203	Mechanics of Materials	4
	or		CHEM 113	General Chemistry II	4
	Elective(HSS)		HSS	Elective	4
CE 110	Computer Applications	4		Total	16
	and GIS		Spring Term		
	Total	17	MA 223	Statistics for Engineers	4
Spring Term			EM 301	Fluid Mechanics	4
MA 113	Calculus III	5	CE 250	Sustainable Civil	2
EM 103	Introduction to Design	2		Engineering Design	
EM 120	Engineering Statics	4	CE 320	C.E. Materials	4
CE 101	Engineering Surveying I	2		Total	14
	Elective(Science)	4			
	Total	17			

Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
CE 321	Structural Mechanics I	4	CE 486	C.E. Design & Synthesis I	2
CE 336	Soil Mechanics	4			
ME 201	Thermodynamics	4		*Elective(Technical)	4
	or		CE 450	C.E. Codes & Regulations	4
CHE 201	Conservation Principles and Balances			Elective(HSS)	4
				Elective(HSS)	4
CE 371	Hydraulic Engineering	4		Total	18
	Total	16			
Winter Term		Credit	Winter Term		Credit
ECE 206	Elements of Electrical Eng.	4	CE 487	Technical System Design & Synthesis	2
	or		CE 488	C.E. Design & Synthesis II	2
CHE 202	Basic Chemical Process Calculations		CE	**C.E. Elective	4
				*Elective(Technical)	4
CE 441	Construction Engineering	2	CE 303	Engineering Economy	4
CE 432	Concrete Design I	3		Total	16
CE 471	Water Resources Engineering	4			
	Elective(Science)	4	Spring Term		Credit
	Total	17	CE 489	C.E. Design & Synthesis III	2
Spring Term		Credit		*Elective(Technical)	4
CE 310	Civil Engineering	2		Elective(HSS)	4
	Numerical Methods			Elective(HSS)	4
CE 431	Steel Design I	3	CE 400	Career Preparation Seminar	0
CE 460	Environmental Engineering	4		Total	14
RH 330	Technical and Professional Communication	4		Total credits required:	194
CE 461	Environmental Engineering Lab	2			
	Total	15			

***A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, or physics.**

****Student shall choose 1 of the following courses as the CE elective:**

- CE 421 Structural Mechanics II**
- CE 442 Cost Engineering**
- CE 563 Unit Operations in Environmental Engineering**

Environmental Engineering Area Minor

The Environmental Engineering Area minor includes 6 required courses and 8 elective credit hours. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their interests.

The 6 required courses are as follows:


- CE 460 Introduction to Environmental Engineering
- CE 471 Water Resources Engineering
- CHEM 264 Introduction to Environmental Science
- CE 563/CHE 461 Unit Operations in Environmental Engineering
- CE 564 Aquatic Environmental Chemistry
- CHEM 251 Organic Chemistry I
- CHEM 251L Organic Chemistry I Laboratory

And 8 credit hours from the following courses:

- CE 561/CHE 450 Air Pollution Control
- CE 562 Treatability Studies
- CE 565 Solid and Hazardous Waste Regulation and Treatment
- CE 566 Environmental Management

CE 567	Applied Hydrologic Modeling
CE 568	Applied Contaminant Transport Modeling
CE 569	Environmental Systems Optimization
CE 573	Groundwater Analysis
CE 590	Special Problems
CE 598	Stream Restoration (Environmental River Mechanics)
CHE 465	Energy and the Environment
CHE 470	Safety, Health, and Loss Prevention
AB 320	Ecology and Environmental Biology

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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. practice their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment

2. continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods

3. function independently and in leadership positions in multidisciplinary teams

4. perform effectively within their profession, their community, and in the public service arena

CPE student outcomes

At the time of graduation, students will have demonstrated :

1. an ability to apply knowledge of mathematics, science, and engineering

2. an ability to design and conduct experiments, as well as to analyze and interpret data

3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

4. an ability to function on multidisciplinary teams

5. an ability to identify, formulate, and solve engineering problems

6. an understanding of professional and ethical responsibility

7. an ability to communicate effectively

8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

9. a recognition of the need for, and an ability to engage in life-long learning

10. a knowledge of contemporary issues

11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The computer engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Computer Engineering Plan of Study

Freshman Year		Sophomore	
Fall Term		Year	
PH 111	Physics I	Credit 4	Fall Term Credit

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

MA 111	Calculus I	5	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	CSSE 232	Computer Architecture I	4
RH 131	Rhetoric and Composition	4	ECE 203	DC Circuits	4
	or		CHEM 111	General Chemistry I	4
HSS	Elective			Total	16
ECE 160	Engineering Practice	2	Winter Term		Credit
	Total	16	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
PH 112	Physics II	4	CSSE 332	Operating Systems	4
MA 112	Calculus II	5	ECE 204	AC Circuits	4
CSSE 120	Introduction to	4	HSS	Elective	4
	Software Development			Total	16
RH 131	Rhetoric and Composition	4	Spring Term		Credit
	or		MA 381	Introduction to Probability	4
HSS	Elective			with Applications	
	Total	17		to Statistics	
Spring Term		Credit	ECE 332	Computer Architecture II	4
PH 113	Physics III	4	ECE 205	Dynamical Systems	4
MA 113	Calculus III	5	HSS	Elective	4
ECE 130	Introduction to	4		Total	16
	Logic Design				
CSSE 220	Object-Oriented	4			
	Software Development				
	Total	17			

Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
MA 275	Discrete & Combinational	4	ECE 460	Engineering Design I	3
	Algebra I			Tech Elective	4
ECE 250	Electronic Device Modeling	4		Area Elective	4
ECE 300	Continuous-Time Signals	4	HSS	Elective	4
	Systems			Total	15
RH 330	Technical and Professional	4	Winter Term		Credit
	Communication		ECE 461	Engineering Design II	4
	Total	16		Tech Elective	4
Winter Term		Credit		Area Elective	4
ECE 380	Discrete-Time Signals Systems	4	HSS	Elective	4
ECE 331	Embedded System Design	4		Total	16
ECE 351	Analog Electronics	4	Spring Term		Credit
	Math/Science Elective	4	ECE 462	Engineering Design III	2
	Total	16		Area Elective	4
Spring Term		Credit	HSS	Elective	4
				Free Elective	4
ECE 333	Digital Systems	4		Free Elective	4
ECE 342	Introduction to	4		Total	18
	Electromagnetic			Total credits required:	194
	Compatibility				
ECE 362	Principles of Design	3			
HSS	Elective	4			
	Total	15			

Area Electives

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Electives

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, geology or physics course as a math science elective except those courses that are cross-referenced with any engineering courses.

Computer Engineering Core Courses

Course Number	Course Title	Credits	Second Major In Computer Engineering		
ECE130	Introduction to Logic Design	4	The ECE Department will not allow the following second major combinations:		
ECE160	Engineering Practice	2			
ECE203	DC Circuits	4	1. Degree in Electrical Engineering and a Second Major in Computer Engineering. 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.		
ECE204	AC Circuits	4			
ECE205	Dynamical Systems	4			
ECE250	Electronic Device Modeling	4			
ECE300	Continuous-Time Signals Systems	4			
ECE331	Embedded System Design	4	Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.		
ECE332	Computer Architecture II	4			
ECE333	Digital Systems	4			
ECE342	Introduction to Electromagnetic Compatibility	4	Course Number	Course Title	Credits
ECE351	Analog Electronics	4	ECE130	Introduction to Logic Design	4
ECE362	Principles of Design	3	ECE203	DC Circuits	4
ECE380	Discrete-Time Signals and Systems	4	ECE204	AC Circuits	4
			ECE205	Dynamical Systems	4
ECE460	Engineering Design I	3	ECE250	Electronic Device Modeling	4
ECE461	Engineering Design II	4	ECE300	Continuous-Time Signals Systems	4
ECE462	Engineering Design III	2			
			ECE331	Embedded System Design	4
			ECE332	Computer Architecture II	4
			ECE333	Digital Systems	4
			ECE342	Introduction to Electromagnetic Compatibility	4
			ECE351	Analog Electronics	4
			ECE380	Discrete-Time Signals and Systems	4
			CSSE120	Introduction to Software Development	4
			CSSE220	Object-Oriented Software Development	4
			CSSE232	Computer Architecture I	4
			CSSE332	Operating Systems	4
			Total		64

Area Minor In Electrical And Computer Engineering (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203
- ECE204

Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

			Example Area Minor for Computer Science and Software Engineering		
Course Number	Course Title	Credits	Course Number	Course Title	Credits
ECE203	DC Circuits	4	ECE130	Introduction to logic Design	4
Required					
ECE204	AC Circuits	4	ECE203	DC Circuits	4
Required			Required		
ECE205	Dynamical Systems	4	ECE204	AC Circuits	4
ECE300	Continuous-Time Signals Systems	4	Required		
ECE380	Discrete-Time Signals and Systems	4	ECE250	Electronic Device Modeling	4
ECE310	Communication Systems	4	ECE332	Computer Architecture II	4
			ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits	Optical Communications Certificate
ECE203	DC Circuits	4	Faculty advisors: B. Black and S. Granieri
Required			
ECE204	AC Circuits	4	Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring
Required			
ECE370	Power & Energy Systems	4	
ECE371	Sustainable Energy Systems	4	
ECE470	Power Systems I	4	
ECE471	Industrial Power Systems	4	

investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)


Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science

The Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The computer science curriculum is designed to prepare students for multiple careers in a rapidly changing environment. The department's courses emphasize fundamental concepts and techniques that will last longer than present technology.

Computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer architecture, programming languages, operating systems, and software engineering. Majors also complete important courses in closely related fields, e.g., discrete mathematics, digital logic design, and probability and statistics. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Courses in database systems, compilers, computer graphics, fractals and chaotic dynamical systems, artificial intelligence, theory of computation, analysis of algorithms, computer networks, computer vision, web-based information systems, and cryptography are available as advanced electives. A three-term senior project provides valuable practical experience in the specification, design, implementation, and documentation of large software systems. Qualified students can undertake independent study in advanced topics in computer science, participate in a research project with a faculty member, or complete a senior thesis.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

Computer science majors have diverse interests and career goals. Five free elective courses allow students to tailor their undergraduate education to their specific goals. Students planning to undertake graduate study in computer science usually take additional advanced courses in computer science, electrical engineering, and mathematics.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Computer science majors have unlimited access to the department's laboratories. Computer science majors are frequently employed by the computing center as user consultants, and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Computer Science Program Educational Objectives

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Student Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering
13. Recognize the need for, and engage in, lifelong learning
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

There are many alternatives to the schedule below. Students with special interests or opportunities (e.g., advanced placement) should determine what schedule is best for their own plan of study by examining schedules at the department's web site: www.cs.rose-hulman.edu.

The computer science program is accredited by the Computing Accreditation Commission of ABET, www.abet.org

Computer Science Plan Of Study

Freshman Year			Sophomore		
Fall Term			Year		
CSSE 120	Introduction to	Credit			
	Software Development	4			
PH 111	Physics I	4	CHEM 111	General Chemistry I	4
MA 111	Calculus I	5	CSSE 232	Computer Architecture I	4
CLSK 100	College & Life Skills	1	MA 212	Matrix Algebra and Systems	4
RH 131	Rhetoric and Composition	4		of Differential Equations	
	Total	18	MA 275	Discrete & Combinatorial	4
Winter Term		Credit		Algebra I	

CSSE 220	Object-Oriented Software Development	4		Total	16
			Winter Term		Credit
PH 112	Physics II	4	CSSE 230	Data Structures and Algorithm Analysis	4
MA 112	Calculus II	5			
HSS	Elective	4	CSSE 333	Database Systems	4
	Total	17	MA 375	Discrete & Combinatorial Algebra II	4
Spring Term		Credit			
CSSE 132	Introduction to Computer Systems	4	HSS	Elective	4
				Total	16
MA 113	Calculus III	5	Spring Term		Credit
HSS	Elective	4	CSSE 304	Programming Lang. Con.	4
Science	Elective	4	ECE 332	Computer Architecture II	4
	Total	17	MA 381	Introduction to Probability with Applications to Statistics	4
			RH 330	Technical and Professional Communication	4
				Total	16
Junior Year					
Fall Term		Credit			
CSSE 371	Software Requirements Engineering	4			
CSSE/MA 473	Design and Analysis of Algorithms	4			
CSSE	Elective	4	Senior Year		
HSS	Elective	4	Fall Term		Credit
	Total	16	CSSE 487	Senior Research Project I or	4
Winter Term		Credit	CSSE 497	Senior Project I or	
CSSE 332	Operating Systems	4	CSSE 494	Senior Thesis I	
CSSE 374	Software Design	4	CSSE	Elective	4
CSSE/MA 474	Theory of Computation	4	HSS	Elective	4
HSS	Elective	4	Free	Elective	4
	Total	16		Total	16
Spring Term		Credit	Winter Term		Credit
CSSE	Elective	4	CSSE 488	Senior Research Project II or	4
	Technical Elective	4	CSSE 498	Senior Project II or	
Free	Elective	4	CSSE 495	Senior Thesis II	
Free	Elective	4	CSSE	Elective	4
	Total	16	HSS	Elective	4
				Technical Elective	4
				Total	14
			Spring Term		Credit
			CSSE 489	Senior Research Project III or	4
			CSSE 499	Senior Project III or	
			CSSE 496	Senior Thesis III	
			Free	Elective	4
			Free	Elective	4
				Total	12
			Total credits required:		192

CSSE electives cannot include any of CSSE 372, 373, 375, 376, and 477.
Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.

HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.
2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
7. A total of 192 credits.

Area Minor in Computer Science

Advisor: Dr. Laxer

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses


CSSE120 Introduction to Software Development

CSSE220 Object-Oriented Software Development

CSSE230 Data Structures and Algorithm Analysis

16 additional credits of computer science courses numbered above 200.

None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories

2. use economic theory to define, analyze and solve a wide range of problems.

3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.

4. communicate complex economics topics in both oral and written form.

5. independently undertake in-depth economic analysis.

Economics Plan of Study

Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	Credit 5	Fall Term		Credit
CLSK 100	College & Life Skills	1	MA 211	Differential Equations	4
RH 131	Rhetoric and Composition	4		Economics Elective	4
	or			*HSS Elective	4
HSS	Elective			Physical or Life Science	4
	Physical or Life Science	4		Total	16
	Total	14	Winter Term		Credit
Winter Term			MA 212		
MA 112	Calculus II	5		Matrix Algebra and Systems of Differential Equations	4
CSSE 120	Introduction to Software Development	4		Economics Elective	4
	Physical or Life Science	4		*HSS Elective	4
RH 131	Rhetoric and Composition	4		Physical or Life Science	4
	or			Total	16
HSS	Elective		Spring Term		Credit
	Total	17	MA 381	Introduction to Probability with Applications to Statistics	4
Spring Term			or		
MA 113	Calculus III	5			

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

SV 151	Principles of Economics	4	MA 223	Engineering Statistics	4
	Physical or Life Science	4		Economics Elective	4
	*HSS Elective	4		*HSS Elective	4
	Total	17		Physical or Life Science	4
				Total	16

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

- 1. 20 credits of required Economics courses:
SV151 Principles of Economics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX496 Seminar for HSS Senior Projects
XX497 Directed Study for HSS Senior Project
- 2. 24 additional credits in Economics electives.
- 3. 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA211, 212 Differential Equations , and Matrix Algebra and Systems of Differential Equations
MA223 Engineering Statistics I or
MA381 Introduction to Probability
- 4. 12 additional credits in Mathematics other than MA351-356.
- 5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
- 6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
- 7. 4 credits in Engineering Management
- 8. 4 credits in Computer Science: CSSE 120
- 9. CLSK 100 (1 credit) and SV 200 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
SV 200	1
TOTAL	193



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

1. practice their profession using a systems approach encompassing technological,economic, ethical, environmental, social, and human issues within a changing global environment

2. continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods

3. function independently and in leadership positions in multidisciplinary teams

4. perform effectively within their profession, their community, and in the public service arena

EE student outcomes

At the time of graduation, students will have demonstrated :

- an ability to apply knowledge of mathematics, science, and engineering

• an ability to design and conduct experiments, as well as to analyze and interpret data

• an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

• an ability to function on multidisciplinary teams

• an ability to identify, formulate, and solve engineering problems

• an understanding of professional and ethical responsibility

• an ability to communicate effectively

• the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context

• a recognition of the need for, and an ability to engage in life-long learning

• a knowledge of contemporary issues

• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET,www.abet.org

Electrical Engineering Plans of Study

Freshman Year			Sophomore		
Fall Term		Credit	Fall Term		Credit
PH 111	Physics I	4			
MA 111	Calculus I	5	MA 211	Differential Equations	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

CLSK 100	College & Life Skills	1	CHEM 111	General Chemistry I	4
RH 131	Rhetoric and Composition	4	ECE 203	DC Circuits	4
	or		ECE 230	Introduction to	4
HSS	Elective			Microcontrollers	
ECE 160	Engineering Practice	2		Total	16
	Total	16	Winter Term		Credit
Winter Term		Credit	MA 212	Matrix Algebra and Systems	4
PH 112	Physics II	4		of Differential Equations	
MA 112	Calculus II	5		Math/Science Elective	4
ECE 130	Introduction to	4	ECE 204	AC Circuits	4
	Logic Design		HSS	Elective	4
RH 131	Rhetoric and Composition	4		Total	16
	or		Spring Term		Credit
HSS	Elective		MA 381	Introduction to Probability	4
	Total	17		with Applications	
Spring Term		Credit		to Statistics	
PH 113	Physics III	4	ECE 205	Dynamical Systems	4
MA 113	Calculus III	5	ECE 370	Power & Energy Systems	4
HSS	Elective	4		or	
CSSE 120	Introduction to	4	ECE 371	Sustainable Energy	
	Software Development			Systems	
	Total	17	HSS	Elective	4
				Total	16

Junior			Senior Year		
Year					
Fall Term		Credit	Fall Term		Credit
ECE 300	Continuous-Time Signals	4	ECE 460	Engineering Design I	3
	Systems			Tech Elective	4
ECE 250	Electronic Device Modeling	4		Area Elective	4
ECE 340	Electromagnetic Fields	4	HSS	Elective	4
RH 330	Technical and Professional	4		Total	15
	Communication		Winter Term		Credit
	Total	16	ECE 461	Engineering Design II	4
Winter Term		Credit		Tech Elective	4
ECE 380	Discrete-Time Signals	4		Area Elective	4
	and Systems		HSS	Elective	4
ECE 351	Analog Electronics	4		Total	16
ECE 341	Electromagnetic Waves	4	Spring Term		Credit
	Math/Science Elective	4	ECE 462	Engineering Design III	2
	Total	16		Area Elective	4
Spring		Credit	HSS	Elective	4
Term				Free Elective	4
ECE 310	Communications Systems	4		Free Elective	4
ECE 320	Linear Control Systems	4		Total	18
ECE 333	Digital Systems	4	Total credits required:		194
ECE 362	Principles of Design	3			
	Total	15			

Area Electives

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Elective

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

Electrical Engineering Plan Of Study

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE160	Engineering Practice	2
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE230	Introduction to Microcontrollers	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE333	Digital Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE 371	Power & Energy Systems or Sustainable Energy Systems	3
ECE380	Discrete-Time Signals and Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

Second Major In Computer Engineering

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE230	Introduction to Microcontrollers	4
ECE250	Electronic Device Modeling	4
ECE300	Continuous-Time Signals Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE333	Digital Systems	4

ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE370	Power & Energy Systems	4
	or	
ECE371	Sustainable Energy Systems	
ECE380	Discrete-Time Signals and Systems	4
MA381	Introduction to Probability with Applications to Statistics	4
Total		64

Area Minor In Electrical and Computer Engineering (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits	Example Area Minor for Computer Science and Software Engineering		
ECE203	DC Circuits	4			
Required			Course Number	Course Title	Credits
ECE204	AC Circuits	4	ECE130	Introduction to logic Design	4
Required			ECE203	DC Circuits	4
ECE205	Dynamical Systems	4	Required		
ECE300	Continuous-Time Signals Systems	4	ECE204	AC Circuits	4
ECE380	Discrete-Time Signals and Systems	4	Required		
ECE310	Communication Systems	4	ECE250	Electronic Device Modeling	4
			ECE332	Computer Architecture II	4
			ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203	DC Circuits	4
Required		
ECE204	AC Circuits	4
Required		
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and

Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

Enhanced Study in Communication Systems

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 410 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Continuous-Time Signals Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Dynamical Systems
- ECE300 Continuous-Time Signals Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

Enhanced Study in Power Systems

Power Certificate

Take all of the following courses:

- ECE 571 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

- 1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
- 2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications





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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Physics

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

EP Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will contribute to society locally, nationally or globally
- Our graduates will collaborate within their organization; and be active in research and development in a relevant area of science and technology.
- Our graduates will continue to develop professionally.

EP Student Learning Outcomes

Outcome A:	Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
Outcome B1:	Interpreting Data: Ability to interpret graphical, numerical, and textual data.
Outcome B2:	System Level Modeling: Ability to model components and system level engineering problems.
Outcome B3:	Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

- Outcome C:

before.
- Outcome D:

Design: Ability to design a product or process to satisfy client's needs subject to constraints.
- Outcome E:

Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
- Outcome F:

Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
- Outcome G:

Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
- Outcome H:

Communication: Ability to communicate effectively in oral, written and visual forms.
- Outcome I:

Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Outcome J:

Life Long Learning: A facility for independent learning and continued professional development.

Engineering Physics (Micro-Nano)

Freshman Year			Sophomore		
Fall Term		Credit	Year		Credit
PH 111	Physics I	4	ES 201	Conservation and	4
MA 111	Calculus I	5		Accounting Principles	
CLSK 100	College & Life Skills	1	PH 235	Many Particle Physics	4
RH 131	Rhetoric and Composition	4	MA 211	Differential Equations	4
EM 104	Graphical Communications	2	PH 292	Physical Optics	4
	Total	16		Total	16
Winter Term		Credit	Year		Credit
PH 112	Physics II	4	EP 280	Intro to Nano Engineering	4
MA 112	Calculus II	5	PH 255	Foundations of	4
CHEM 111	General Chemistry I	4		Modern Physics	
CSSE 120	Introduction to	4	MA 212	Matrix Algebra and Systems	4
	Software Development			of Differential Equations	
ME 123	or		ES 202	Fluid & Thermal Systems	3
	Computer Applications I			Total	15
	Total	17			
Spring Term		Credit	Year		Credit
PH 113	Physics III	4	HSS	Elective	4
MA 113	Calculus III	5	OE 295	Optical Systems	4
CHEM 113	General Chemistry II	4	SV 151	Principles of Economics	4
OE 172	Optics in Technology*	2	ES 203	Electrical Systems	4
EM 103	Introduction to Design**	2		Total	16
	Total	17*			
Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
PH 316	Electric and Magnetic Fields	4	EP 416	Engineering Physics	4
HSS	Elective	4		Project II	
PH 405	Semiconductor Materials	4	EP 411	Advanced topics in MEMS	4
	and Applications		OE 495	Optical Metrology	4
MA 223	Engineering Statistics I	4		Engineering Elective	4
	Total	16		Total	16
Winter Term		Credit	Winter Term		Credit
HSS	Elective	4	EP 417	Engineering Physics	4
PH 317	Electromagnetism	4		Project III	
RH 330	Technical and	4	HSS	Elective	4
	Professional Communication.			Elective	4
EP 406	Semiconductor Devices	4	PH 401	Intro Quantum Mechanics	4
	and Fabrication			Total	16
	Total	16			
Spring Term		Credit	Spring Term		Credit
EP 380	Nanotechnology,	4	HSS	Elective	4
	Entrepreneurship and Ethics		HSS	Elective	4
				Science Elective	4

EP 410	Intro to MEMS	4	Engineering Elective	4
EP 415	Engineering Physics Project I	4	or	
	Engineering Elective	4	EP 408 Microsensors	
	or		Total	16
EP 408	Microsensors		Total credits required:	193
	Total	16		

***If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.**

EP 415, EP 416, and EP 417 are courses the student can take from any engineering department where the student has an area of concentration. The projects will have industrial clients that emphasize both physics and engineering and it may be jointly administered with the respective departments.
EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

Subjects	#Classes Hours	
Physics(PH)	10	40
Math(MA)	6	27
Chemistry(CHEM)	2	8
Computer Science(CSSE)/ME	1/0 or 0/1	4
EM	2	4
CLSK	1	1
Engineering Science	3	11
Optical Engineering (OE)	3	10
HSS	9	36
Engineering Physics (EP)	6	24
Engineering Physics Project(EP)	3	12
Elective(Science, Eng. and Free)	4	16
Total	50	193

Summary of Graduation Requirements for Engineering Physics

- 1. All the courses listed above by the number.
- 2. The program must be approved by the EP advisor.
- 3. A list of the engineering electives is provided.
- 4. An engineering elective is any RHIT course in an engineering discipline.
- 5. Science electives are courses that should be taken in the physics, chemistry, math, or biology programs.
- 6. A free electives is any course in engineering, science, humanities, military science, or air science.

Classes by Subjects	Hours	General Foundation Classes	
Physics Coursework*	40	Course Description	Hours
Chemistry and Mathematics Coursework**	35	PH 111 Physics I	4
Humanities and Social Science(Standard requirement)	36	PH 112 Physics II	4
Computer Science, EM, CLSK Courses	9	PH 113 Physics III	4
Engineering Science Classes	11	MA 111 Calculus I	5
Other Engineering Classes (Optical)	10	MA 112 Calculus II	5
EP Courses	24	MA 113 Calculus III	5
EP Projects	12	MA 211 Differential Equations	4
Engineering Electives	8	MA 212 Matrix Algebra and Systems of Differential Equations	4
Science and Free Electives	8	MA 223 Engineering Statistics	4
Total	193	CHEM Engineering Chemistry I 105	4
		CHEM Engineering Chemistry II 107	4
Foundation Physics Classes		Total	47
Course Description	Hours		
PH 235 Many Particle Physics	4		
PH 255 Foundations of Modern Physics	4		
PH 316 Electric & Magnetic Fields	4		

PH 317 Electromagnetism	4
PH 401 Introduction to Quantum Mechanics	4
Total	20

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	2
OE 172	Optics in Technology	2
ES 201	Conservation and Accounting Principles	4
ES 202	Fluids and Thermal Systems	3
ES 203	Electrical Systems	4
EP 280	Introduction to Nano-engineering	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
EP 411	Advance Topics in MEMS	4
OE 495	Optical Metrology Engineering Elective	8
CSSE	Computer Programming	4
120/ME 123		
Total		67

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	4
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Recommended Engineering Electives: Requires the approval of the advisor.
The EP advisory committee can modify this list and add more courses over time.

- ECE 204 AC Circuits
 - ECE 205 Dynamic Systems
 - ECE 351 Analog Electronics
 - ME 424 Composite Materials & Mechanics
 - OE 485 Electro-Optics & Applications
 - OE 450 Laser Systems
 - ME 328 Engineering of Materials
 - CHE 315 Materials Science & Engineering
 - EP 440/407* Advanced Materials
- * indicates a course that is under development.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Mathematics

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

Program Goals and Objectives

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

Degree Requirements

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Continuous Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- The project must involve work done by the student(s) to solve a problem presented by an external sponsor. The written project submission must be signed by the student's project advisor (who must be a member of the mathematics department) and two

additional members (who are approved by the project advisor), and must be presented publicly to the department. The additional members of the committee may include representatives of the sponsor.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team). The written submission must be signed by the student's thesis advisor (who must be a member of the mathematics department) and two additional faculty members (who are approved by the thesis advisor), and must be presented publicly to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.

Total hours required for graduation
195 hrs.

*PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
AB 101 — Essential Biology (or higher-level AB course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.

**CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	

***200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.

**** CLSK 100 — College and Life Skills	1 hr.
MA 200 Career Preparation	1 hr.

Suggested Schedule

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math

elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended basic chemistry course is CHEM 105 unless a student is taking a second major or minor requiring CHEM 111 or credit for CHEM 111 has already been received. If CHEM 111 is taken instead of CHEM 105 then the order of the basic science electives in the freshman and sophomore is the second science course listed. Two science courses are to be taken in the winter quarter of freshman year

Mathematics

Freshman Year

Fall Term			Credit
MA	111	Calculus I	5
PH	111	Physics I	4
		or	
CHEM	111	General Chemistry I	4
RH	131	Rhetoric and Composition	
		or	4
HSS		Elective	
CLSK	100	College and Life Skills	1
CSSE	120	Introduction to Software Development	4
			16
			18

Winter Term			Credit
MA	112	Calculus II	5
PH	112	Physics II	4
		or	
PH	111	Physics I	4
CHEM	111	General Chemistry I	
		or	4
AB	101	Essential Biology (or higher level AB course)	
HSS		Elective	4
		or	
RH	131	Rhetoric Composition	4
			17

Spring Term			Credit
MA	113	Calculus III	5
PH	113	Physics III	4
		or	
PH	112	Physics II	4
MA	190	Contemporary Mathematics Problems	
HSS		Elective	4
			15

Junior Year

Fall Term			Credit
MA		Elective	4
		Technical Elective	4
		Technical Elective	4
HSS		Elective	4
		or	
RH	330	Technical and Professional Communication	4

Sophomore Year

Fall Term			Credit
MA	211	Differential Equations	4
MA	275	Disc. & Comb. Algebra I	4
AB	101	Essential Biology (or higher level AB course)	4
		or	
PH	113	Physics III	4
*CSSE	220	Object-Oriented Software Development	
			16
Winter Term			Credit
MA	212	Matrix Algebra and Systems of Differential Equations	4
		Science Elective	4
		Technical Elective	4
HSS		Elective	4
**MA	200	Career Preparation	1
			17

Spring Term			Credit
MA	381	Introduction to Probability	4
MA	371	Linear Algebra I	4
		Technical Elective	4
HSS		Elective	4
			16

Senior Year

Fall Term			Credit
MA	491	Intro to Math Modeling (2 hours)	4
MA	492	Senior Project I (2 hours)	
		or	4
MA	496	Senior Thesis I (4 hours)	
		Free Elective	4
		Free Elective	4

				HSS	HSS	4
			16			
Winter Term						
			Credit			16
MA	366	Functions of a Real Variable	4			
MA		Elective	4	Winter Term		
		Technical Elective	4			Credit
		Elective				
HSS		or		MA	493	Senior Project II (2 hours)
						or
			4			2
				MA	497	Senior Thesis II (2 hours)
RH	330	Technical and Professional Communication		MA		Elective
						4
						Free Elective
						4
			16			Free Elective
						4
Spring Term						
			Credit			18
MA		Elective	4			
MA		Elective Technical Elective	4	Spring Term		
			4			Credit
HSS		Elective				
		or	4	MA	494	Senior Project III (2 hours)
						or
						2
RH	330	Technical and Professional Communication		MA	498	Senior Thesis III (2 hours)
				MA		Elective
						4
			16			Free Elective
						4
						Free Elective
						4
						14

Total credits required: 195

Notes:

- *MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework
- **MA 200 - Career Preparation - may be taken in either the winter or spring quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- Math Elective:** A course either required by the concentration or a true math elective.
- Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- Free Elective:** Any course.

Computational Science Major (CPLS) (Second Major Only)

Computational methods are widely employed in science and engineering for simulation, experimentation, analysis, and design. In many areas the use of high-performance computing is essential. The Computational Science major provides Rose-Hulman students with the opportunity to add to their primary major a second major that increases their knowledge and skill in applied scientific and engineering computation.

Requirements for a second major in Computational Science (71 credit hours)

The second major in Computational Science is open to all students. It requires 71 credit hours, including a 55 credit hour core and a 16 credit hour specialization. The courses used to satisfy the requirements in the Advanced Core may not be counted toward any other major or minor. All Computational Science programs of study are subject to approval by the Chair of the Computational Science Steering Committee

I. Computational Science Core (55 credit hours)

Fundamentals (35 credit hours)

- MA 111, 112, 113 Calculus I, II, III
- MA 211 Differential Equations
- MA 212 Matrix Algebra and Systems of Differential Equations
- CSSE 120 (1) Introduction to Software Development, or any of BE 100, CE 110, CHE 110 (plus 2 cr.), ME 123
- CSSE 132 or ECE130 Introduction to Computer Systems, Introduction to Logic Design
- MA 332 (2) Introduction to Computational Science, or any of CE 310 (plus 2 cr.) CHE 310, ME 323(plus 2 Credits)

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any upper-level computational science course (see list below)

List of Advanced Electives

- BE 510 Biomedical Signal and Image Processing
- CHE 521 Advanced Chemical Engineering Computation
- CSSE 304 Programming Language Concepts
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- ECE 582/PH 537 Advanced Image Processing
- EMGT 526 Technology Forecasting
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 348 Continuous Optimization
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis
- MA 435 Finite Difference Methods
- MA 439 Mathematical Methods of Image Processing
- MA 444 Deterministic Models in Operations Research
- MA 446 Combinatorial Optimization
- MA 490 Mathematical Biology
- ME 422 Finite Element Methods for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Elements Analysis
- Other courses may be counted as advanced electives upon approval by the Chair of Computational Science.

II. Area of Concentration (16 credit hours): Each student must complete 16 credit hours in an area of concentration within Computational Science. Courses used to satisfy the core requirements may not be used to satisfy the area of concentration requirements.

Computational Methods

- MA 371 or MA 373 Linear Algebra I, Applied Linear Algebra for Engineers
- MA 433 Numerical Analysis
- Eight credit hours chosen from CSSE 304, CSSE/MA 473, MA 348, MA 386, MA 434, MA 435,

MA439, MA 444, MA 446, MA 485, ME 422

Computational Mechanics

- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- ME 401 Foundations of Fluid Mechanics
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Element Analysis

Computational Signals and Image Processing

- ECE 380 Discrete-Time Signals and Systems
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- MA 439 Mathematical Methods of Image Processing

Computational Physics and Chemistry

- CHEM 361 Physical Chemistry I
- CHEM 362 Physical Chemistry II
- CHEM 363 Quantum Chemistry & Molecular Spectroscopy
- OE 570 Nanomedicine
- PH 540 Computer Physics

Computational Biomedics

- BE 482/MA 482 Bioengineering Statistics
- BE 535/OE 535 Biomedical Optics
- BE 541/ECE 597 Medical Imaging
- MA 490-01 Mathematical Biology 1
- MA 490-02 Mathematical Biology 2

Area Minor in Mathematics

A student, not pursuing a major or second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student’s advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.

- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

Area Minor in Computational Science

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing

- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the major.
- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

Area Minor in Statistics

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- **Globally required mathematics courses**
MA 111 Calculus I
MA 112 Calculus II
MA 113 Calculus III
MA 212 Differential Equations
- **Required Introductory Statistics/Probability Courses:**
MA 381 Introduction to Probability with Applications to Statistics,
One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is taken before MA223/MA382 the student will be strongly recommended to take MA382.
- **Required Second Statistics Course**
One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics
- **Electives**
3 courses (12 credits) selected from the following list, at least two of which must be starred. Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.

MA 385* Quality Methods
MA 386* Statistical Programming
MA 387* Statistical Methods in Six Sigma
MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers
MA 445 Stochastic Models in Operations Research
MA 481* Mathematical Statistics
MA 485* Regression and Time Series Analysis
MA 487* Design of Experiments
MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students

- Only MA111, MA112, MA113, MA212 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.



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Admissions

Academics

Student Life

News

Calendars

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Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Mechanical Engineering

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Since mechanical engineering is a broad field of endeavor, the curriculum offers a strong technical elective program to allow each student to craft a broad educational experience and to develop the flexibility to pursue diverse career goals.

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Design Processes and Methodology.

The strength of any department is its faculty. The mechanical engineering faculty is committed to providing a dynamic and innovative learning environment and to maintaining and increasing their technical competence in a rapidly changing world. Stereotypes notwithstanding, they understand that people are more important than things. Thus, they encourage each student to seek them out when he or she has academic problems or needs guidance in career planning.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 12 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

Vision: To graduate the best baccalaureate mechanical engineers.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

- a. *an ability to apply knowledge of mathematics, science, and engineering*
- b. *an ability to design and conduct experiments, as well as to analyze and interpret data*
 1. *Identify the problem and develop an appropriate experimental approach*
 2. *Select measurement techniques to collect appropriate data and justify that selection.*
 3. *Estimate experimental uncertainties.*
 4. *Collect and present data in an accurate and orderly way.*
 5. *Use appropriate statistical procedures to analyze and evaluate the information contained in a data set.*
 6. *Analyze the data and draw supportable conclusions from the result*
- c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
 1. *Understand the problem.*
 2. *Develop a design specification that addresses customer/client needs and constraints.*
 3. *Carry out a conceptual design by generating multiple solutions that address the requirements of the design specification.*
 4. *Evaluate the feasibility of the solutions.*
 5. *Choose an appropriate solution and justify that solution*
 6. *Carry out a conceptual-level design using appropriate design tools and methodologies.*
 7. *Test and refine the implementation until the product or process design specifications are met or exceeded.*
 8. *Document the finished product or process as appropriate for the discipline according to standard practice.*
- d. *an ability to function on multi-disciplinary teams*
 1. *Demonstrate how you reached a decision as a team.*
 2. *Describe the team role you filled and how that contributed to the final project.*
 3. *Listen openly, actively, and critically.*
- e. *an ability to identify, formulate, and solve engineering problems*
 1. *Inspect and define the problem.*
 2. *Identify the basic principles and concepts that apply to the situation.*
 3. *Build appropriate model(s).*
 4. *Solve the problem by choosing appropriate tools (analytical, experimental, and computational).*
 5. *Check a solution using appropriate criteria.*
- f. *an understanding of professional and ethical responsibility*
 1. *Explain important ethical obligations associated with your discipline.*
 2. *Apply a systematic ethical framework to an ethical issue or situation in a disciplinary context.*
- g. *an ability to communicate effectively*
 1. *Provide a substantive critique that includes recommendations for improvements.*
 2. *Adapt technical information for a non-specialized audience.*
 3. *Convey information effectively through visual media.*

4. *Present information visually using drawings, graphs and sketches.*
5. *Deliver oral presentations with clarity and professionalism.*
- h. *the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
 1. *Engage in the arts (music, theater, art, dance, creative writing, etc.)*
 2. *Analyze patterns, dynamics, or values of human interaction in social or cultural systems.*
 3. *Analyze beliefs, backgrounds, cultures, or societies different from your own.*
 4. *Interpret cultural artifacts and/or ideas in philosophy, the arts, or the sciences.*
- i. *a recognition of the need for, and an ability to engage in life-long learning*
 1. *Students will describe how their current state of performance in an ability has already impacted or might in the future negatively impact their project or team.*
 2. *Students will describe steps they will follow to reach their desired performance level in the ability.*
 3. *Students will describe evidence that indicates that they have achieved their professional development goal.*
 4. *Students will describe the "most significant" professional development they achieved and explain its impacts.*
 5. *Students will explain what they have learned about the professional development process that will transfer into life after graduation.*
- j. *a knowledge of contemporary issues*
 1. *Students will identify the problem.*
 2. *Students will describe the problem from different perspectives (At least two sides)*
 3. *Students will identify stakeholders and describe how stakeholders are affected*
 4. *Students will justify arguments logically.*
 5. *Students will reference sources appropriately.*
- k. *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

Area Minor*** in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

ME 301 Thermodynamics II
CHE 303 Chem. Engineering Thermodynamics
ME 302 Heat Transfer
CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems

ME 407 Power Plants**
ME 408 Renewable Energy
ME 409 Air Conditioning*
ME 410 Internal Combustion Engines
ME 411 Propulsion Systems**
ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundation of Fluid Mechanics
- ME 402 Advanced Heat Transfer*
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics**
- ME 502 Topics in Heat Transfer*
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

**Requires one of the thermodynamics prerequisites from section 2 above.
* Requires one of the heat transfer prerequisites from section 2 above.
*** ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may include special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

- ECE/ME 497 Introduction to Model-Based System Design
- ECE/ME 497 Advanced Model Based-System Design

Elective Courses

- CHEM 470 Combustion Chemistry

- ECE 320 Linear Control Systems
- or
- ME 406 Control Systems

- ECE 420 Nonlinear Control Systems
- or
- ME 506 Advanced Control Systems

- ECE 370 Machines & Power
- ECE 410 Communication Networks
- ECE 452 Power Electronics

- ME 408 Renewable Energy
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 422 Finite Elements for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 450 Combustion

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

MA 336 Boundary Value Problems

ME 405 Theoretical Aerodynamics

ME 401 Foundation of Fluid Mechanics

ME 411 Propulsion Systems

ME 422 Intro to Finite Element Fundamentals

ME 426 Turbomachinery

ME 427 Introduction to Computational Fluid Dynamics

ME 461 Aerospace Design

ME 503 Viscous Flow

ME 510 Gas Dynamics

ME 512 Light Weight Structures

ME 522 Advanced Finite Element Analysis

PH 322 Celestial Mechanics

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

CE 561 or CHE 450 Air Pollution (cross-listed class)

CE 590 Climate Change Assessment

CHE 490 Energy and Environment

CHE 512 Petrochemical Processes

ECE 370 Power and Energy Systems

ECE 371 Industrial Power Systems

ME 407 Power Plants

ME 408 Renewable Energy

ME 450 Combustion

ME 501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities,

Social Sciences list

Math List

MA 385 Quality Methods

MA 487 Design of Experiments

MA 387 Statistical Methods in Six Sigma

Engineering Management List

EMGT 330 Introduction to Engineering Management

EMGT 427 Project Management

EMGT 520 Accounting for Technical Managers

EMGT 521 Financial Management in a Technical Environment

EMGT 522 Organizational Management

EMGT 523 Marketing Issues in a Technical Environment 4

EMGT 524 Production/Operations Management

EMGT 526 Technology Management and Forecasting

EMGT 527 Project Management

EMGT 531 Economics for Technical Managers

EMGT 532 Technical Entrepreneurship

EMGT 533 Intercultural Communication

EMGT 534 Management Science

EMGT 535 Strategies for Organizational Change

EMGT 586 Supply Chain Management

EMGT 587 Systems Engineering

EMGT 588 Quality Management I

EMGT 589 Manufacturing Systems

Humanities, Social Sciences List

GS 350 International Trade

GS 351 International Finance

IA 230 Fundamentals of Public Speaking

SV 151 Principles of Economics

SV 350 Managerial Accounting

SV 351 Managerial Economics

IA 352 Game Theory

SV 303 Business and Engineering Ethics

SV 304 Bioethics

SV 352 Money & Banking

SV 353 Industrial Organization

SV 354 Environmental Economics

SV 356 Corporate Finance

EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

EMGT 330 Introduction to Engineering Management

EMGT 427 Project Management

EMGT 588 Quality Management

EMGT 589 Manufacturing Systems

MA 385 Quality Methods

ME 317 Design for Manufacturing

ME 417 Advanced Materials Engineering

ME 435 Robotics

ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics

- ME 502 Topics in Heat Transfer
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the ****Thermal Fluid Systems****list and at least two courses are taken from the ****Thermal Fluid Sciences****list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Mechanical Engineering Plan of Study


Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	5	Fall Term		Credit
PH 111	Physics I	4	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	ES 201	Conservation &	4
EM 104	Graphical Communications	2		Accounting Principles	
RH 131	Rhetoric and Composition	4	ES 203	Electrical Systems	4
	split fall or winter with		HSS	Elective	4
HSS	Elective		Total		16
	Total	16	Winter Term		Credit
Winter Term					
MA 112	Calculus II	5	MA 212	Matrix Algebra and	4
PH 112	Physics II	4		Systems	
ME 123	Computer Applications I	4	ES 202	Fluid & Thermal Systems	3
RH 131	Rhetoric and Composition	4	ES 204	Mechanical Systems	3
	split fall or winter with		CHEM 111	General Chemistry I	4
HSS	Elective		HSS	Elective	4
	Total	17	Total		18
Spring Term			Spring Term		
MA 113	Calculus III	5	MA 223	Statistics for Engineers	4
PH 113	Physics III	4	ES 205	Analysis & Design of	4
EM 103	Introduction to Design	2		Engineering Systems	
EM 121	Statics and Mechanics	4	CHEM 113	General Chemistry II	4
	of Materials I		HSS	Elective	4
	Total	15	Total		16

Junior			Senior Year		
Year			Fall Term		
Fall Term		Credit	ME 430	Mechatronic Systems	4
ME 301	Thermodynamics II	4		split fall or winter with	
EM 204	Statics and Mechanics	4	ME 421	M.E. Lab and *Tech Elective	(2+4)
	of Materials I		ME 406	Control Systems	4
ECE 207	Elements of Electrical Engrg II	4		or	
*Free	Elective	4	EM 406	Vibration Analysis	(4)
Total		16	ME 480	Machine Component Design	4
Winter Term				split Jr. spring or Sr. fall with	
ME 317	Design for Manufacturing	(3) 3	ME 470	Engineering Design Proc & Method	(3)
ME 321	Measurement Systems	4	*Tech	Elective	(4) 4
	split winter or spring with		Total		(17) or 16
ME 323	Computer Applications II	(2)	Winter Term		
			ME 471	Capstone Design I	(3) 3

Science	Elective	(4)		ME 421	M.E. Lab and *Tech Elective	2+4
ME 328	Materials Engineering	(4)	4		split fall or winter with	
RH 330	Technical Communications	(4)		ME 430	Mechatronic Systems	(4)
	split winter or spring with			HSS	Elective	(4) 4
HSS	Elective	4		*Free	Elective	(4) 4
	Total	(17) or			Total	(15) or 17
		15		Spring Term		Credit
Spring Term		Credit		ME 472	Capstone Design II	3
ME 302	Heat Transfer	(4)	4	*Tech	Elective	4
ME 323	Computer Applications II	2		**Adv. Tech	Elective	4
Science	Elective	4		HSS	Elective	4
	split winter or spring with				Total	15
ME 321	Measurement Systems	(4)		Total credits required:		194
ME 470	Engineering Design Proc & Method	3				
ME 480	split Jr. spring or Sr. fall with	(4)				
	Machine Component Design					
HSS	Elective	(4)				
	split winter or spring with					
RH 330	Technical Communications	4				
	Total	(16) or				
		17				

*24 credit hours. in electives composed of 16 cr. hrs. in technical electives, of which at least 4 cr. hrs. must be in advanced level courses and 8 cr. hrs. in free electives. (i.e. 12 cr. hrs. tech. electives, 4 cr. hrs. adv. tech elective, 8 cr. hrs. free electives)

** An **advanced technical elective** is designated with an * in the undergraduate bulletin ME and EM course description section or any 500 level course and above in BE, ChE, CE, CPE, EE, ME, OE or SE programs. A technical elective is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A **science elective** is any course in applied biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.

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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

OE Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will make a meaningful impact on society.
- Our graduates will behave ethically and act as responsible members of the engineering and science community.
- Our graduates will continue to develop professionally

OE Student Learning Outcomes

- Outcome A:

Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering
- Outcome B1:

Interpreting Data: Ability to interpret graphical, numerical, and textual data
- Outcome B2:

System Level Modeling: Ability to model components and system optical engineering problems
- Outcome B3:

Experimentation:Ability to design and conduct experiments to understand the relationships

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

	between variables in a problem which may or may not have been mathematically modeled before
Outcome C:	Design: Ability to design a product or process to satisfy client's needs subject to constraints
Outcome D:	Team work: Ability to work in multi-disciplinary teams and understand the effective team dynamics and be able to deliver a product
Outcome E:	Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world optical engineering problems
Outcome F:	Professional Practice and Ethics: A sound understanding what an optics professional is and have an awareness and understanding of professional ethics
Outcome G:	Communication: Ability to communicate effectively in oral, written and visual forms
Outcome H:	Contemporary issues and global awareness: An awareness of contemporary issues in engineering profession and the role of professionals in an interdependent global society
Outcome I:	Life Long Learning: A facility for independent learning and continued professional development

The optical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Optical Engineering

Freshman Year

Fall Term				Credit
MA	111	Calculus I	5	
PH	111	Physics I	4	
CLSK	100	College and Life Skills	1	
RH	131	Rhetoric and Composition	4	
EM	104	Graph Comm	2	
				16

Winter Term				Credit
PH	112	Physics II	4	
MA	112	Calculus II	5	
CHEM	111	General Chemistry I	4	
ME	123	Computer Applications I	4	
				17

Spring Term				Credit
PH	113	Physics III	4	
MA	113	Calculus III	5	
CHEM	113	General Chemistry II	4	
OE	172	Optics in Tech	2	
EM	103	Intro Eng. Design	2	
				17

Junior Year

Fall Term				Credit
PH	316	Elec & Mag Fields	4	
OE	360	Optical Materials and Opto-Mechanics	4	
PH	405	S.C. Mat & Appl.	4	
ECE	205	Dynamical Systems	4	

Sophomore Year

Fall Term				Credit
MA	223	Engineering Statistics		
		or		4
SV	151	Principles of Economics		
PH	235	Many-Part Physics		4
MA	211	Differential Equations		4
PH	292	Physical Optics		4
				16

Winter Term				Credit
ECE	203	DC Circuits		4
PH	255	Fnd. of Mod. Phys.		4
		Matrix Algebra and Systems of		
MA	212	Differential Equations		4
OE	280	Paraxial Optics		4
				16

Spring Term				Credit
		Free Elective		4
OE	295	Optical Systems		4
SV	151	Principles of Economics		
		or		4
MA	223	Engineering Statistics		
ECE	204	AC Circuits		4
				16

Senior Year

Fall Term				Credit
OE	480	Lens Des & Abb		4
OE	495	Optical Metrology		4
HSS		Elective		4
OE	416	Opt Eng Des II		4

				16			
				16			
				Winter Term			
Winter Term						Credit	
				Credit			
OE	393	Fiber Opt & App	4	OE	485	Electro-Opt. & App.	4
		Free Elective	4	HSS		Elective	4
						Engineering Elective	4
EP	406	SC Dev & Fab	4	OE	417	Opt Eng Des III	4
HSS		Elective					
		or	4				
RH	330	Technical and Professional Communication					16
				Spring Term			
						Credit	
				16			
Spring Term						Credit	
				Credit			
						Engineering Elective	4
				HSS		Elective	4
				HSS		Elective	4
						Free Elective	4
OE	415	Opt Eng Des I	4				
HSS		Elective	4				
HSS		Elective					16
		or	4				
RH	330	Technical and Professional Communication					
				Total credits required: 194			
OE	450	Laser Systems	4				
				16			

If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

Summary of Graduation Requirements for Optical Engineering

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects

	Hours
Optics Coursework	46
Physics Coursework	20
Freshmen Physics, Chemistry and Mathematics Coursework	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous	25
Total	194

Physics Classes

Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4
PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4

Total **20**

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM105	Engineering Chemistry I	4
CHEM107	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
EP 406	Semiconductor Devices and Fabrication	4
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
Total		25

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required Courses

Course	Hours	Course Description
--------	-------	--------------------

OE 280	4	Paraxial Optics
PH 292	4	Physical Optics
OE 295	4	Optical Systems

Plus at least two courses from one of the areas listed below:

Lens Design Area

Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 480	4	Lens Design and Aberrations
OE 490	4	Directed Research (4 Credits Only)

Photonics/Electro-optics Area

Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-optics and Applications
OE 490	4	Directed Research (4 credits only)
OE 493	4	Fundamentals of Optical Fiber Communications

Image Processing Area

Course	Hours	Course Description
OE 415	4	Optical Engineering Design I
OE 490	4	Directed Research (4 Credits Only)
PH 437/ECE 480	4	Introduction to Image Processing
PH 537/ECE 582	4	Advanced Image Processing

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)
Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203	4	DC Circuits
ECE 204	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within

the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

- 1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
- 2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

Physics

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
MA	111	Calculus I	5			Free Elective†	4
PH	111	Physics I	4	PH	235	Many Particle Physics	4
CLSK	100	College and Life Skills	1	MA	211	Differential Equations	4
RH	131	Rhetoric and Composition		PH	292	Physical Optics	4
		or	4				
HSS		Elective					16
EM	104	Graphical Communications	2				
			16				
Winter Term				Winter Term			
			Credit				Credit
PH	112	Physics II	4	PH	255	Fund. of Modern Physics	4
MA	112	Calculus II	5			Elective	4
CHEM	111	General Chemistry I	4	HSS		Technical Elective	4
		Computing Elective*	2-4			Matrix Algebra and Systems of	
				MA	212	Differential Equations	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

- Additional Programs of Study
- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

				15 or 17				16	
						<i>Spring Term</i>			
<i>Spring Term</i>								<i>Credit</i>	
				<i>Credit</i>					
PH	113	Physics III	4	PH	314	Theoretical Mechanics I		4	
MA	113	Calculus III	5	HSS		Elective		4	
CHEM	113	General Chemistry II	4	MA	371	Linear Algebra I		4	
HSS		Elective				Math Elective†		4	
		or	4						
RH	131	Rhetoric and Composition							16
				17					
Junior Year				Senior Year					
<i>Fall Term</i>				<i>Fall Term</i>				<i>Credit</i>	
				<i>Credit</i>					
HSS		Elective	4	Math		Elective†		4	
PH	316	Electric and Magnetic Fields	4			Technical Elective†		4	
		Technical Elective†	4	HSS		Elective		4	
PH	405	Semiconductor Materials and Applications	4			Free Elective		4	
								16	
				16					
<i>Winter Term</i>				<i>Winter Term</i>				<i>Credit</i>	
				<i>Credit</i>					
PH	317	Electromagnetism	4	PH	425	Advanced Physics Lab II		4	
				HSS		Elective		4	
PH	401	Intro Quantum Mechanics	4			Technical Elective†		4	
HSS		Elective	4			Free Elective†		4	
		Physics Elective†	4						
								16	
				16					
<i>Spring Term</i>				<i>Spring Term</i>				<i>Credit</i>	
				<i>Credit</i>					
PH	325	Advanced Physics Lab I	4	OE	450	Technical Elective†		4	
HSS		Elective	4			Laser Sys & App			
OE	450	Laser Sys & App				or		4	
		or	4			Physics Elective			
		Physics Elective†				Free Elective		4	
PH	327	Thermodynamics & Statistical Mechanics	4			Physics Elective†		4	
								16	
				16					
								Total credits required: 192	

* Computing elective: 2 or 4 credit course on computing from the following course: AB 140, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

Summary of Graduation Requirements for Physics Majors

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be

- directed research (PH290 or PH490) with at least one credit of PH490.
- Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
 - Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
 - Sixteen credits of free electives (cannot include ECE340).
 - Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
 - A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.
 - A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
PH 215	Introduction to Chaos	2
PH 231	Intro to Astronomy and Astrophysics	4
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 322	Celestial Mechanics and Solar	4
PH 330	Material Failure	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
PH 407	Solid State Physics	4
PH 437	Introduction to Image Processing	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	Arranged
PH 470	Directed Research	Arranged
PH 480	Seminar	Arranged
PH 490	Directed Research	Arranged
PH 497+	Senior Thesis	Arranged
PH 498+	Senior Thesis	Arranged
PH 499+	Senior Thesis	Arranged
PH 512	Methods of Mathematical Physics	4
PH 514	Quantum Mechanics	4
PH 530	Advanced Acoustics	4
PH 537	Advanced Image Processing	4
PH 538	Introduction to Neural Networks	4

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year for a total number of 8 credit hours over

the three quarter sequence. Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

****Math and Chemistry Courses:**

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	
	Linear Algebra	4
MA 371	General Chemistry I	4
CHEM 111	General Chemistry II	4
CHEM 113		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

Area Minor Programs

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus 12 credit hours from the following courses:

Course	Course Title	Hours
PH 270/470	Special Topics in Physics †	ARR
PH 290/490	Directed Research †	ARR
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4
PH 460	Directed Study †	ARR

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 290/490	Directed Research	2

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4
PH 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
PH 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental

Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

The software engineering program prepares its graduates for many types of careers in the computing industry as well as for graduate study in software engineering and in closely related disciplines. Within a few years after completing the software engineering degree program, our graduates will:

- Advance beyond their entry-level position to more responsible roles, or progress towards completion of advanced degree(s).
- Continue to keep pace with advancements in their disciplines, and develop professionally in response to changes in roles and responsibilities.
- Demonstrate that they can collaborate professionally within or outside of their disciplines at local, regional, national, or international levels.
- Contribute to the body of computing products, services, or knowledge.

Software Engineering Student Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The software engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Software Engineering

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
CSSE	120	Introduction to Software Development	4	CHEM	111	General Chemistry I	4
MA	111	Calculus I	5	CSSE	232	Computer Architecture I	4
PH	111	Physics I	4	MA	212	Matrix Algebra and Systems of Differential	4
RH	131	Rhetoric & Composition	4	MA	275	Equations Discrete & Combinatorial Algebra I	4
CLSK	100	College and Life Skills	1				
			18				16

Winter Term				Winter Term			
			Credit				Credit
CSSE	220	Object-Oriented Software Development	4	CSSE	230	Data Structures and Algorithm Analysis	4
MA	112	Calculus II	5	CSSE	333	Database Systems	4
PH	112	Physics II	4	MA	375	Discrete & Combinatorial Algebra II	4
HSS		Elective	4			Domain track course	4
			17				16

Spring Term				Spring Term			
			Credit				Credit
CSSE	132	Introduction to Computer Systems Design	4	CSSE	304	Programming Lang. Con	4
MA	113	Calculus III	5	CSSE	376	Software Quality Assurance	4
HSS		Elective	4	MA			
Science		Elective	4	RH	330	Elective Technical and Professional Communication	4
			17				16

Junior Year				Senior Year			
Fall Term				Fall Term			
			Credit				Credit
CSSE	371	Software Requirements Engineering	4	CSSE	477	Software Architecture	4
CSSE	372	Software Project Management	4	CSSE	497	Senior Project I	4
MA	381	Introduction to Probability with Statistical Applications	4	HSS		Elective	4
		Domain track course	4			Domain track course or free elective	4
			16				16

Winter Term				Winter Term			
			Credit				Credit
CSSE	332	Operating Systems	4	CSSE	498	Senior Project II	4
CSSE	374	Software Design	4	CSSE		Elective	4
HSS		Elective	4	HSS		Elective	4
		Domain track course	4	Free		Elective	4
			16				16

Spring Term				Spring Term			
			Credit				Credit
CSSE	373	Formal Methods in Specification and Design	4	CSSE	499	Senior Project III	4
CSSE	375	Software Construction and Evolution	4	HSS		Elective	4
HSS		Elective	4	Free		Elective	4
		Domain track course or free elective	4				12
			16				

Total credits required: 192

Summary of graduation requirements for the software engineering major

To complete the major in software engineering a student must complete the following:

- 1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220,

CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE477, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA212, MA275, MA375, MA381; PH111, PH112, CHEM111; RH 131, RH330; CLSK100.

- 2. One additional CSSE elective course except CSSE 325, CSSE 473, CSSE 474, and CSSE 479. In addition, use of CSSE 49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.
- 3. A Domain Track set of courses. All of the courses for each of the Domain Tracks is listed on the CSSE website at <http://csse.rose-hulman.edu/SE-DomainTracks>. That site also explains the procedures and deadlines by which a student must declare their Domain Track.
- 4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
- 5. Four credits of science electives, which can be any CHEM, GEOL, PH, or AB courses not already required for the software engineering major.
- 6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
- 7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

CSSE 120, Introduction to Software Development
CSSE 220, Object-Oriented Software Development
CSSE 230, Data Structures and Algorithm Analysis
CSSE 371, Software Requirements Engineering
CSSE 374, Software Design

Two additional courses in software engineering chosen from CSSE 372, 373, 375, 376, and 477.



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Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Aerospace Studies

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation-contact Air Force ROTC for more details.

Scholarships

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

Profession of Arms Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.

Communications Skills Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

General Military Courses

Freshman Year			Credit	Sophomore			Credit
AS 101	Found. of the US Air Force I		1	Year			
AS 101L	Leadership Laboratory		0	AS 201	Evol. of Air & Space Power I		2
AS 102	Found. of the US Air Force II		1	AS 201L	Leadership Laboratory		0
AS 102L	Leadership Laboratory		0	AS 202	Evol. of Air & Space Power		2
AS 103	Found. of the US Air Force III		1		II		
AS 103L	Leadership Laboratory		0	AS 202L	Leadership Laboratory		0
				AS 203	Evol. of Air & Space Power		2
					III		
				AS 203L	Leadership Laboratory		0

Professional Officer Courses

Junior Year			Credit	Senior			Credit
AS 301	Air Force Lead. Studies I		4	Year			
AS 301L	Leadership Laboratory		0	AS 401	Nat.Sec.Aff./Prep. for Active Duty		4
AS 302	Air Force Lead. StudiesII		4		I		
AS 302L	Leadership Laboratory		0	AS 401L	Leadership Laboratory		0
AS 303	Air Force Lead. Studies III		4	AS 402	Nat.Sec.Aff./Prep. for Active Duty		4
AS 303L	Leadership Laboratory		0		II		
				AS 402L	Leadership Laboratory		0
				AS 403	Nat.Sec.Aff./Prep. for Active Duty		4
					III		
				AS 403L	Leadership Laboratory		0

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.



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Trustees
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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Military

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

Curriculum

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at<http://www.rose-hulman.edu/AROTC/>

Partnership Institutions

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College, University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

Freshman Year

			<i>Credit</i>
MS	101	Leadership and Personal	1
MS	102	Development	1
MS	103	Introduction to Tactical Leadership	1
		Basic Tactical Leadership	

Sophomore Year

			<i>Credit</i>
MS	201	Innovative Team	2
MS	202	Leadership	2
MS	203	Foundations of Tactical Leadership	2
		Foundations of Tactical Leadership II	

Summer

			<i>Credit</i>
MS	206	ROTC Basic Camp	0

ADVANCED COURSE

Junior Year

			<i>Credit</i>
MS	301	Adaptive Team Leadership	4
MS	302	Leadership Under Fire	4
MS	303	Leadership Under Fire II	4

Senior Year

			<i>Credit</i>
MS	401	Developing Adaptive	4
MS	402	Leaders	4
MS	403	Leadership in a Complex World	4
		Leadership in a Complex World II	

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training..



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Incoming Freshman

Faculty and Staff
Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose-Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs



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[Incoming Freshman](#)

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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies (Air Force ROTC)

LT Col Adkins, MAJ Parks, CAPT Blystone

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Pre: None

This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Pre: AS 101 or instructor permission

This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Pre: AS 102 or instructor permission

This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Pre: Enrollment in AS 101, AS 102, or AS 103
Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Pre: AS 103 or instructor permission

This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Pre: AS 201 or instructor permission

This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Pre: AS 202 or instructor permission

This course is a continuation of the winter quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Pre: Enrollment in AS 201, AS 202, or AS 203

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Pre: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Pre: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Pre: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Pre: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Pre: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Pre: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Pre: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Pre: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Applied Biology & Biomedical Engineering

Applied Biology and Biomedical Engineering Faculty: Ahmed, Anthony, Buckley, Chiu, Coppinger, Dee, Ingram, Livesay, O'Connor, Rogge, Waite, and Weiner

AB 101 Essential Biology 4R-OL-4C F,W,S Pre: None
Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed AB110, AB120 or AB130 cannot receive credit for taking AB101.

AB 102 Nutrition 4R-OL-4C W Pre: none
This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for AB or BE majors and not as an AB elective.

AB 110 Cell Structure and Function 3R-3L-4C F,S Pre: None
Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

AB 120 Comparative Anatomy & Physiology 3R-3L-4C W Pre: None
The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

AB 130 Evolution and Diversity 3R-3L-4C S Pre: None
Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

AB 191 Special Topics in Applied Biology XR-OL-XC Arranged Pre: Consent of instructor
Covers material of mutual interest to students and instructors which cannot be acquired in any other listed AB course.

AB 205 Cellular Physiology 4R-OL-4C F Pre: AB110
The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for AB205 cannot earn credit for AB210 or AB230 without departmental consent.

AB 210 Mendelian and Molecular Genetics 3R-3L-4C F Pre: AB 110 or instructor consent
A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

AB 220 Prokaryotic Cell and Molecular Biology 3R-3L-4C W Pre: AB 110 or instructor consent
Discusses the essential properties of eubacteria and archaea. Bacterial nutrition, growth, genetics and structural and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

AB 230 Eukaryotic Cell and Molecular Biology 3R-3L-4C S Pre: AB 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

AB 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111, or CHEM 105 or CHEM 201, or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

AB 310 Plant Structure & Function 3R-3L-4C S Pre: AB 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

AB 320 Ecology 3R-3L-4C F Pre: AB 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

AB 330 Evolutionary Biology 4R-0L-4C W Pre: AB 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

AB 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Pre: AB120, and Jr/Sr standing or consent of instructor

Designed to introduce applied biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

AB 399 Practice of Science 4R-0L-4C Pre: RH330 and MA223, or consent of instructor

This course focuses on skills required for implementing scientific research, including reading the primary literature, experimental design, scientific writing, oral presentations, research proposal writing, poster presentations, and investigation of research programs (through seminars or individual meetings). Each student chooses a project and research mentor by the end of the course.

AB 410 Infection and Immunity 4R-0L-4C Arranged Pre: AB 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

AB 411 Genetic Engineering 4R-0L-4C Arranged Pre: AB 205 or AB 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

AB 421 Applied Microbiology 4R-0L-4C Arranged Pre: AB110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

AB 431 Genomics and Proteomics 4R-0L-4C S Pre: AB 205 or AB210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

AB 441 Virology 3R-3L-4C Pre: AB110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

AB 451 Cancer Biology 4R-0L-4C Pre: AB 205 or AB210 or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to

these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

AB 461 Evolutionary Medicine 4R-0L-4C Arranged Pre: AB130, and AB205 or AB210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

AB 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged Pre: AB 205 or AB210 or consent of instructor

Strategies and methods used to identify and understand the genetic and molecular bases of inherited human disease are addressed. Topics include, human population genetics, pedigrees, genetic and physical mapping of human genes, linkage analysis, and diagnostic testing. Primary literature is routinely utilized.

AB 491 Special Topics in Applied Biology XR-0L-XC Arranged Pre: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed AB course.

AB 492 Directed Study in Applied Biology XR-XL-XC Arranged Pre: Consent of instructor

Covers applied biology material of mutual interest to the student and instructor which cannot be experienced in any other listed AB course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the ABBE department is required to use this course to fulfill AB elective credit requirements.

AB 496 Senior Thesis Research I 0R-6L-2C F, W, S Pre: AB 399 and consent of instructor

Initiation of senior thesis under the direction of an ABBE faculty mentor. Major tasks include creation and submission of a research proposal and piloting procedures. Additional requirements for adequate progress determined by each faculty mentor.

AB 497 Senior Thesis Research II 0R-12L-4C F, W, S Pre: AB 399 and consent of instructor

Continuation of research under the direction of an ABBE faculty mentor. Major tasks include data acquisition and methodological refinement. Additional requirements for adequate progress determined by each faculty mentor.

AB 498 Senior Thesis Research III 0R-12L-4C F, W, S Pre: AB 399 and consent of instructor

Continuation of research under the direction of an ABBE faculty mentor. Major tasks include data acquisition and preliminary analysis. Additional requirements for adequate progress determined by each faculty mentor.

AB 499 Senior Thesis Research IV 0R-6L-2C W Pre: AB 399 and consent of instructor

Completion of senior thesis under the direction of an ABBE faculty mentor. Major tasks include final analysis, public presentation of results, and submission of the written thesis. Additional requirements for adequate progress determined by each faculty mentor.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4CW Pre: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE201 Biomedical Measurements 3R-3L-4C Pre: BE100, ES203

Discuss the measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors (temperature, force, pressure, velocity, etc), and basics of PIC microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I: 3R-3L-4C W Pre: AB120, AB205

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Pre: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of cradle to cradle design processes. Current biomedical industry processes and issues are

emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II: 3R-3L-4C S Pre: BE310

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3CC W Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE351 and BE361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Instrumentation and Signal Processing 3R-3L-4C F Pre: Pre: BE 201 and ES 203, or consent of instructor

Topics include Circuit analysis, frequency analysis, biomedical transducers, design of biomedical devices, and introduction to imaging techniques.

BE 350 Biocontrol Systems 4R-0L-4C Pre: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE351: Biomedical Engineering Lab 1R-3L-2C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331 and BE361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE352: Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE353: Biomaterials Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Pre: BE 201, Coreq: EM204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 400 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Pre: BE390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications,

planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Pre: BE410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Pre: BE420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 482 Bioengineering Statistics 4R-0L-4C Pre: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Pre: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Pre: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F, W, S Pre: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing, 3R-3L-4C W Pre: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Human Physiology A 3R-3L-4C W Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Human Physiology B 3R-3L-4C S Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Pre: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Pre: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 535.

BE 539 Multiscale Biomechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541 Medical Imaging 4R-0L-4C Pre: JR/SR/GR standing and consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including computed tomography, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed.

BE 543 Neuroprosthetics 3R-3L-4C Pre: BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Pre: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Pre: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Pre: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Pre: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 565 Experimental Methods in Tissue-Biomaterial Interactions 3R-3L-4C S Pre: BE 361, or consent of instructor

This course focuses on teaching students experimental methods used for investigations of tissue-biomaterial interactions. Topics include bioethics issues associated with experiments on cells, tissues, animals, and people; biosafety issues associated with cells/tissues from animals and humans; the design, critique, and statistical analysis of experiments. Students conduct hands-on investigations of cell-biomaterial interactions which require the use of common laboratory equipment, aseptic technique, mammalian cell culture, and current molecular methods to investigate cell viability, structure, and function.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Pre: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 F,W,S

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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News

Calendars

Alumni

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemical Engineering

Professors Artigue, Coronell, Hariri, D. Henthorn, K. Henthorn, McClellan, Nolte, Sauer, and Serbezov.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Pre: None

An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 1R-0L-0C F Pre: sophomore standing in Chemical Engineering

Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F Pre: CHEM 113 or concurrent registration in CHEM 112, MA 113 or concurrent registration, and PH 111 or concurrent registration

An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Pre: CHE 201

The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 300 Career Preparation II 0L-0C F Pre: Junior standing in Chemical Engineering

Career choices; preparation of resume; preparation for summer positions; preparation for graduate programs. 2-5 contact hours per quarter.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Pre: CHE 201

Physical properties of fluids, fluid statics, laminar and turbulent flow, boundary layer concept, flow past objects and flow through porous media. Design of pipe networks and pumps. High speed ideal gas flow. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Pre: CHE 202, MA211

First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F, W Pre: CHE 303, MA212

Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Pre: CHE 110, MA211, MA212 or concurrent enrollment

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Pre: CHEM 115 or consent of instructor

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Pre: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304

Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Pre: CHE 320, CHE 304

Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Pre: CHEM 360 and CHE 304

The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Pre: Senior Standing in Chemical Engineering

Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Pre: CHE 321, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Pre: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Pre: CHE 321

Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Pre: CHE 416, CHE 404

Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Pre: CHE 417 or consent of instructor

Completion of an open-ended design project that will include written and oral communication of intermediate

results and a final written report.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W Pre: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F Pre: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 450 Air Pollution 4R-0L-4C F or W Pre: Junior or Senior standing

An introduction to air pollution and its control with special emphasis on the engineering aspects. Discussions of meteorology, health effects, sources and types of pollution, industrial control technology. Student projects. Cross-listed with CE561.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Pre: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Pre: CHE 303 or CHEM361 or ME201 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S Pre: Junior or Senior standing

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F, W, S Pre: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

Undergraduate-Graduate Courses

CHE 502 Transport Phenomena I 4R-0L-4C Pre: CHE 321 or consent of instructor

Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 503 Transport Phenomena II 4R-0L-4C

Energy Transport: multidimensional systems; macroscopic balances for nonisothermal systems. Mass Transport: fundamentals of ordinary diffusion, multicomponent diffusion, pressure and thermal diffusion, coupled heat and mass transfer, boundary layer analysis, turbulent transport, mass transfer coefficients, macroscopic balances.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W (proposed) Pre: CHE 321 or consent of instructor

Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 511, ME 519, and ECE 519.

CHE 521 Advanced Chemical Engineering Computation 4R-0L-4C

The application of advanced mathematics to chemical engineering problems. The topics include: the formulation of the partial differential equations of kinetics and heat, mass and momentum transfer problems; series solution techniques; transform solution techniques; vector formulation; numerical methods for systems of differential equations; optimization, including linear programming, combinatorial optimization, and stochastic optimization techniques.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: AB110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: AB110, CHE 321 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

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Advanced Placement

Graduate Studies

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Chemistry

Professors Adcock, Allison, Brandt, R. DeVasher, Erwin, Morris, Mottel, Mueller, Sunahori, Tilstra, Weatherman, and Wilson

CHEM 111 General Chemistry I 3R-3L-4C F,W,S Pre: None
Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 112 Chemistry Honors 4R-3L-5C F Pre: Advanced placement
An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-4C W,S Pre: CHEM 111
Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 115 General Chemistry III 3R-3L-4C W, S Pre: CHEM 113 or CHEM 112
Topics in this course include acid-base reactions, electrochemistry, and coordination chemistry.

CHEM 200 Career Preparation 1R-0L-1C W,S
This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with MA200, and SV200.

CHEM 225 Analytical Chemistry 3R-3L-4C F, S Pre: CHEM 115
This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 251 Organic Chemistry I 3R-0L-3C F Pre: CHEM 113 or CHEM 112, Coreq: CHEM251L
An introduction to the classification of organic compounds, their structural features, including stereochemistry, and concepts related to reaction mechanisms and synthetic methods.

CHEM 251L Organic Chemistry I Laboratory 0R-3L-1C F Pre: CHEM 113 or CHEM 112, Coreq: CHEM251
Organic Laboratory techniques are developed along with appropriate spectroscopic methods. Assessment is in part via practicums. Computational chemistry methods and green chemistry approaches are also introduced.

CHEM 252 Organic Chemistry II 3R-0L-3C W Pre: CHEM 251, CHEM 251L, Coreq: CHEM 252L
Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis, and an introduction to the methods used to determine structure, including IR and NMR spectroscopy and mass spectrometry.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

CHEM 252L Organic Chemistry II Laboratory 0R-3L-1C W Pre: CHEM 251, CHEM 251L, Coreq: CHEM 252

A continuation of CHEM251L where additional, more complicated synthetic techniques and methods along with additional spectroscopic techniques are introduced. Assessment is in part via practicums.

CHEM 253 Organic Chemistry III 3R-0L-3C S Pre: CHEM 252, CHEM 252L, Coreq: CHEM 253L

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 253L Organic Chemistry III Laboratory 0R-4L-1C S Pre: CHEM 252, CHEM 252L, Coreq: CHEM 253

Project based laboratory where techniques and skills developed in the previous organic laboratories are applied to more open-ended problems.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with AB264.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Pre: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Pre: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research under the direction of a member of the faculty selected by mutual agreement. Freshman and/or sophomore students may earn up to 2 credits and are required to submit a written report to the chemistry faculty.

CHEM 291 Introduction to Chemical Research 3R-3L-4C W Pre: CHEM 113 or CHEM 112

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members.

CHEM 304 Glassblowing 1R-3L-1C S Pre: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Pre: CHEM 225

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Pre: CHEM 225

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Pre: CHEM 252

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Pre: CHEM 330 and AB 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C

W, S Pre: CHE 303, CHE 304, and CHEM115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Pre: CHEM 115, MA 212 and MA 381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the

applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Pre: CHEM 111, MA 212, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 371 Environmental Analytical Chemistry (3R-4L-4C) F Pre: CHEM251 (or concurrent enrollment), and CHEM 225 and CHEM 264

This course is a laboratory-driven course where processes involved in performing environmental analytical chemistry are addressed. The focus of this course is on the chemical principles, analytical theory, instrumentation, and methods employed to quantitatively and qualitatively analyze pollutants in soil, water, biological tissues, and the atmosphere. Several techniques will be included in the course: sampling (obtaining a representative sample of complex system); sample preparation (extraction, clean-up, pre-concentration, derivitization, digestion, etc.); data acquisition (The laboratory will include use of EPA/ASTM methods/protocols, method development, etc.); and data handling and analysis (statistics, signals, noise, etc.).

CHEM 400 Chemical Communication I 1R-0L-1C W Pre: CHEM291

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. The emphasis of this course is to provide instruction in written communication. The fundamental skills useful for composition of professional chemistry communications is introduced culminating in a research prospectus. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 401 Chemical Communication II 1R-0L-1C F Pre: CHEM400 and CHEM490

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. Students will learn methods associated with constructing results and analysis sections of formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 402 Chemical Communication III 1R-0L-1C W Pre: CHEM 401

The emphasis of this course is to provide instruction in oral communication. Students will be taught fundamental skills useful for public presentation of research and its results. Students will also be required to attend the chemistry department's seminar series.

CHEM 403 Chemical Communication IV 1R-0L-1C S Pre: CHEM 402

Students will publish a thesis and deliver a professional seminar on their undergraduate research.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Pre: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 431 Biochemical Instrumentation 3R-4L-4C Pre: AB 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 433 Biochemistry Laboratory 0R-3L-1C S Pre: CHEM 330

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Pre: CHEM 252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Pre: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field

are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 445 Organometallic Chemistry 4R-0L-4C S Pre: CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 451 Organic Structure Determination 2R-8L-4C S Pre: CHEM 253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 452 Synthetic Organic Chemistry 4R-0L-4C F or W Pre: CHEM 253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 454 Theoretical Organic Chemistry 4R-0L-4C W Pre: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 455 Natural Products 4R-0L-4C Pre: CHEM 253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 457 Synthetic Polymer Chemistry 4R-0L-4C Pre: CHEM 252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 461 Advanced Physical Chemistry 4R-0L-4C Pre: CHEM 363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 462 Physical Polymer Chemistry 4R-0L-4C Pre: CHEM 361 or CHE 303

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Pre: CHEM 251 or CE 564 or consent of instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F, W, S Pre: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.

Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: Permission of instructor

Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Pre: CHEM291

Research under the direction of a member of the faculty selected by mutual agreement. Students may earn a maximum of 18 credits between CHEM 290 and CHEM 490. Students may register for 1 to 3 credits per quarter.



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Course Descriptions

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Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Civil Engineering

CE 321 Structural Mechanics I 4R-0L-4C F Pre: EM 203

Aerospace Studies (Air Force ROTC)
Applied Biology & Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Military Science (Army ROTC)
Multi-Disciplinary Studies
Optical Engineering
Physics
Robotics
Sophomore Engineering

Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Pre: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Pre: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE 400 Career Preparation Seminar 1R-0L-0C S Pre: CE 489

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 410 Senior Project 0R-8L-4C On Demand Pre: Senior class standing

Gives the student the opportunity to work on a civil engineering design or research project of the student's own choice, but which has met the approval of the staff prior to the start of the quarter. Requires presentation of oral and written reports. Not a regular elective offering.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Pre: CE 321

Matrix methods of structural analysis for two- and three- dimensional indeterminate structures. Force method, stiffness method, introduction to finite element analysis for civil engineers.

CE 424 Composite Material Mechanics 4R-0L-4C On Demand Pre: CE 321

Introduces various laminated composite materials such as reinforced plastics, laminated glass, plywood, laminated timber, and fiber-structural sandwich. Emphasis is on beam theory and plane stress analysis for such materials.

CE 430 Structural Design in Timber I 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of modern structures constructed of timber. Considers fasteners and their significance in design. Develops design criteria and their application to plane and three dimensional structures.

CE 431 Structural Design in Steel I 3R-0L-3C S Pre: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Pre: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 433 Structural Design in Steel II 4R-0L-4C On Demand Pre: CE 431

Covers the analysis and design of the various elements of a steel structure within the framework of the total structure. Includes composite design, plate girders, and multi-story building frames.

CE 434 Structural Design in Concrete II 3R-3L-4C Pre: CE 432

Advanced topics in reinforced concrete analysis and design such as strut-and-tie modeling, and strengthening with fiber reinforced polymers.

CE 435 Bridge Engineering 4R-0L-4C On Demand Pre: CE 321

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Includes methods and procedures for the analysis and design of bridge structures. Considers standards and procedures for inspections and ratings of bridges and methods to increase the load capacity of existing bridges. Includes field inspections.

CE 436 Foundation Engineering 4R-0L-4C S Pre: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Pre: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C F Pre: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 444 Pavement Design and Highway Construction 4R-0L-4C On Demand Pre: CE 320

Introduction to analysis and design of rigid and flexible pavement systems; subgrade, subbase, base and surfaces; specifications, material testing and construction methods for soil stabilization, flexible and rigid pavements; pavement evaluation, maintenance and reconstruction.

CE 445 Construction Methods and Equipment 4R-0L-4C F Pre: CE 201 and CE 336, Co: CE 442

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Pre: CE 431 & CE 432

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will also look at environmentally safe and renewable building materials, energy efficient construction techniques, indoor air quality and moisture problems, etc. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Pre: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Co: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 471 Water Resources Engineering 4R-0L-4C W Pre: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Transportation Planning 4R-0L-4C On Demand Pre: Junior class standing

Analyzes the transportation planning process. Stresses goals and approaches to solutions as related to the urban transportation problem. Includes a class project.

CE 481 Transportation Engineering 4R-0L-4C W Pre: Senior class standing

Study of transportation functions and transportation systems including land, air and marine modes; transportation system elements including travel way, vehicle, controls and terminals; emphasis on highway geometric design.

CE 482 Urban Planning 4R-0L-4C On Demand Pre: Junior class standing

Applies general principles of systems analysis and control to urban and regional planning. Covers human settlements, location theory, simulation, plan formulation, selection and implementation. Includes a class project.

CE 486 Civil Engineering Design & Synthesis I, F, 1 R-3L-2C Pre: RH 330, CE 460 Co-Req: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be initiated by small teams of students to implement principles used in planning, design, and synthesis. Learning objectives include contracting, concept development, concept feasibility, planning and scheduling design work, data collection for subsequent design.

CE 487x Technical System Design & Synthesis W, 2R-2L-2C Pre: CE486 Co-Req: CE 488

Technical system design of subdisciplinary elements of civil engineering projects submitted by corporate and governmental sponsors will be completed by individual team members to fulfill the needs of a team project initiated with CE486 and continuing in CE488. The "x" will be used to identify subdiscipline designation (c = general civil design, e= environmental, g = geotechnical, s = structural, t = transportation, w = water resources).

CE 488 Civil Engineering Design & Synthesis II, W, 1R-2L- 2C, winter Pre: CE486 Co-Req: CE 487

Project management by small teams for civil engineering projects submitted by corporate and governmental sponsors will continue. Learning objectives include coordinate of major design work in subdisciplines, progress reporting to the client, critical path model management to keep the project on schedule to fulfill the needs of a team project initiated with CE486 and continuing in CE487.

CE 489 Civil Engineering Design & Synthesis III, S, 1R-3L-2C Pre: CE 487, CE488

Civil engineering projects submitted by corporate and governmental sponsors will be completed. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. Learning objectives include construction planning and cost, final reporting, and public presentation of findings.

CE 490 Directed Studies F,W,S 1-4 C Arranged. Pre: Approval of department head, adviser, and course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

Undergraduate-Graduate Courses

CE 520 Plates and Shells 4R-0L-4C On Demand Pre: CE 421 and MA 212

Development of classical plate equation and boundary conditions; solution of problems in rectangular and polar coordinates. Development of membrane and bending theories for shells of revolutions; solution to domes and storage tanks.

CE 522 Advanced Finite Element Analysis 4R-0L-4C On Demand Pre: CE 421

Development of finite element methods for solving plane strain, plane stress and field problems. Utilizes readily available finite element computer programs. Requires additional development of user computer programs.

CE 523 Structural Dynamics 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of structures subjected to dynamic loads. Covers elastic and inelastic responses with applications to earthquake design, blast-resistant structures and bridge vibration.

CE 525 Buckling Strength of Structures 4R-0L-4C On Demand Pre: CE 321

Discusses the buckling phenomenon of prismatic bars subjected to combined axial and transverse loads. Considers elastic and inelastic instability. Includes buckling of beams, columns, curved bars, rings, plates, trusses and rigid frames.

CE 530 Structural Design in Timber II 4R-0L-4C On Demand Pre: CE 430

Presents the analysis and design of structures constructed of timber. Tapered beams, curved beams, box beams, stressed-skin panels, tapered columns, built-up columns, laminated arches, plate connected trusses, pole structures, diaphragms, shearwalls.

CE 531 Structural Design in Masonry 4R-0L-4C S Pre: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 533 Behavior of Metal Structures 4R-0L-4C On Demand Pre: CE 433

Discusses the behavior of metal connectors, members and structures. Studies the significance of this behavior in terms of design and the development of specifications. This course is closed to students who have successfully completed CE 433 Structural Design in Steel II.

CE 534 Behavior of Concrete Structures 4R-0L-4C On Demand Pre: CE 432

Studies the behavior of beams, slabs, and columns of reinforced concrete, prestressed concrete and composite construction from the standpoint of design and the development of specifications.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C On Demand Pre: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Pre: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 561 Air Pollution 4R-0L-4C W Pre: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Treatability Studies 2R-6L-4C On Demand Pre: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 563 Unit Operations in Environmental Engineering 4R-0L-4C F Pre: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Pre: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Pre: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Pre: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Pre: CE 471

Environmental planning and management strategies are examined using computer simulation models. Students will be introduced to some of the most widely used models in the fields of hydrology, hydraulics, and stormwater quality (nonpoint source pollution).

CE 568 Applied Contaminant Transport Modeling 4R-0L-4C On Demand Pre: CE 460 or consent of instructor

Environmental planning and management strategies are examined using computer simulation models. Emphasis is on pollutant transport in various media and emerging pollution issues. Students are introduced to some of the most widely used models in the field of environmental engineering. Students also develop at least one pollutant transport model using common software such as EXCEL, MATHCAD.

CE 569 Environmental Systems Optimization 4R-0L-4C Pre: Senior or Graduate class standing

Application of the principles of operations research to constrained optimization of environmental systems. Typical topics include strategies for non-linear searches, linear programming, dynamic programming, etc.

CE 570 Fluid Mechanics in Water Resources Engineering 4R-0L-4C On Demand Pre: CE 371

Presents steady and unsteady flow problems in open channels and pipes, problems dealing with laminar and turbulent boundary layers, and problems including diffusion and dispersion. There will be occasional laboratory work to demonstrate physical modeling in water resources engineering.

CE 573 Groundwater Analysis 4R-0L-4C Pre: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Pre: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Pre: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A

comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Advanced Placement

Graduate Studies

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Professors Anderson, Bohner, Boutell, Chenoweth, Defoe, Hewner, Laxer, Mellor, Mohan, Mutchler, Rupakheti, Shillingford, M. Taylor, and Wollowski

CSSE 120 Introduction to Software Development 3R-3L-4C F, W, S

An introduction to procedural and object-oriented programming with an emphasis on problem solving. Students will solve problems by developing software in both an interpreted language (Python) and a compiled language (C). Problems may include visualizing scientific or commercial data, interfacing with external hardware such as robots, or solving numeric problems from a variety of engineering disciplines. Procedural programming concepts covered include data types, variables, control structures, arrays, and data I/O. Object-oriented programming concepts covered include object creation and use, object interaction, and the design of simple classes. Software engineering concepts covered include testing, incremental development, understanding requirements, and teamwork.

CSSE 132 Introduction to Computer Systems 3R-3L-4C F,S Pre: CSSE 120

Provides students with an understanding of system level issues and their impact on the design and use of computer systems. Examination of both hardware and software layers. Basic computation structures and digital logic. Representation of instructions, integers, floating point numbers and other data types. System requirements, such as resource management, security, communication and synchronization, and their hardware and/or software implementation. Exploration of multiprocessor and distributed systems. Course topics will be explored using a variety of hands-on assignments and projects.

CSSE 220 Object-Oriented Software Development 3R-3L-4C F,W,S Prerequisite: CSSE 120

Object-oriented programming concepts, including the use of inheritance, interfaces, polymorphism, abstract data types, and encapsulation to enable software reuse and assist in software maintenance. Recursion, GUIs and event handling. Use of common object-based data structures, including stacks, queues, lists, trees, sets, maps, and hash tables. Space/time efficiency analysis. Testing. Introduction to UML.

CSSE 221 Fundamentals of Software Development Honors 3R-3L-4C F Prerequisite: A score of 4 or 5 on the APCS A exam or permission of instructor

This course is intended for students who have sufficient programming experience to warrant placement in an accelerated course covering the topics from CSSE 120 and CSSE 220. This course will satisfy the prerequisite requirements for courses that have CSSE 220 as a prerequisite.

CSSE 230 Data Structures and Algorithm Analysis 3R-3L-4C W,S Prerequisites: CSSE 220 or CSSE 221 with a grade of C or better, and MA 112

This course reinforces and extends students' understanding of current practices of producing object-oriented software. Students extend their use of a disciplined design process to include formal analysis of space/time efficiency and formal proofs of correctness. Students gain a deeper understanding of concepts from CSSE 220, including implementations of abstract data types by linear and non-linear data structures. This course introduces the use of randomized algorithms. Students design and implement software individually, in small groups, and in a challenging multi-week team project.

CSSE 232 Computer Architecture I 3R-3L-4C F, W Prerequisites: CSSE 132, or CSSE 120 and ECE 130

Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic,

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control.

Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prerequisite: CSSE 220 or CSSE 221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE290 Special Topics in Computer Science 1 - 4C Arr. Prerequisite: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prerequisite: CSSE230 and MA275

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arr Prerequisites: CSSE 220 or CSSE 221, and MA 212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W, S Prerequisites: CSSE 220 or CSSE 221, and CSSE 132 or CSSE 232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prerequisite: MA 275 and CSSE 230 (or concurrent enrollment in CSSE 230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prerequisites: CSSE 220 or CSSE 221, and MA 212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 371 Software Requirements Engineering 4R-0L-4C F Prerequisite: CSSE 230, RH 330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requisite: CSSE 371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict management. Professional issues including career planning, lifelong learning, software engineering ethics, and

the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prerequisite: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Design 4R-0L-4C W Prerequisite: CSSE 371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 4R-0L-4C S Prerequisite: CSSE 374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prerequisite: CSSE 230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prerequisite: CSSE 332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prerequisite: CSSE 304

A survey of some current and emerging programming languages, focusing on unique language paradigms—ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prerequisites: CSSE 232, CSSE 304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prerequisite: CSSE 230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prerequisite: CSSE 220 or CSSE 221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 433 Advanced Database Systems 4R-0L-4C S Prerequisite: CSSE 333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prerequisites: CSSE 332 and MA 275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure

design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prerequisite: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence 4R-0L-4C Arr Prerequisite: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prerequisites: CSSE 220 or CSSE 221, and MA 212 (MA 371 or MA 373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prerequisites: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prerequisites: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prerequisites: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 477 Software Architecture 4R-0L-4C F Pre: CSSE 374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 479 Cryptography 4R-0L-4C S Prerequisites: CSSE 220 or CSSE 221, and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prerequisite: CSSE 230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE487 Senior Research Project I 4C Arr Prerequisite: RH330 and senior standing

CSSE488 Senior Research Project II 4C Arr Prerequisite: CSSE487

CSSE489 Senior Research Project III 4C Arr Prerequisite: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arr Prerequisite: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arr Prerequisite: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arr Prerequisite: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arr Prerequisite: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arr Prerequisite: RH 330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arr Prerequisite: CSSE 494

CSSE 496 Senior Thesis III 4C Arr Prerequisite: CSSE 495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Project I 4C F Prerequisite: CSSE 371

CSSE 498 Senior Project II 4C W Prerequisite: CSSE 374 and CSSE 497

CSSE 499 Senior Project III 4C S Prerequisite: CSSE 498

Group software engineering project requiring completion of a software system for an approved client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure.



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Professors C. Berry, Black, Doering, Eccles, Grigg, Herniter, Hoover, Hudson, Moore, Mu, Padgett, Radu, Rostamkolai, Simoni, Song, Throne, P. Walter, Wheeler, and Yoder.

ECE 130 Introduction to Logic Design 4R-0L-4C F,W,S Pre: None
Combinational logic analysis and design, Boolean algebra, gate-level optimization, switch-level circuits, propagation delay, and standard combinational components. Sequential circuit analysis and design, flip-flops, timing diagrams, registers, counters, and finite state machine controllers. Design projects using circuit simulator and implementation in hardware.

ECE 160 Engineering Practice 0R-4L-2C F, W Pre: none
The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

ECE 203 DC Circuits 3R-3L-4C F, W, S Pre: MA111 and PH112
Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

ECE 204 AC Circuits 3R-3L-4C F, W, S Pre: ECE203 with a grade of C or better and PH113
Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Dynamical Systems 3R-3L-4C F, W, S Pre: ECE204 and MA211
Review of matrix and differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical and mechanical systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C W,S Pre: MA 211
A course designed for engineers (other than electrical or computer) covering analysis of passive circuits, introduction to op-amps, instrumentation, sinusoidal steady-state, a-c power, and induction motors. EE and CPE majors may not take this course.

ECE 207 Electrical Engineering 3R-3L-4C F,W Pre: ES 203
A course designed for engineers (other than electrical or computer) covering AC power, three-phase systems, magnetic circuits, transformers, machines, strain gauges, RTDs and thermocouples, noise and shielding, and feedback systems. Integral laboratory. EE or CPE majors may not take this course.

ECE 230 Introduction to Microcontrollers 3R-3L-4C F, W Pre: ECE130, CSSE120
Development of embedded systems with microcontrollers. Microcontroller architecture, instruction set, programmer's model, hardware modules, and assembly language programming. Data representation and

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

storage. Memory management. The C programming language, data structures and programming styles. Input and output devices. Data communications. Sensors and actuators. Real-time event measurement, generation and control. Interrupt generation and processing. Labs and a term project.

ECE 250 Electronic Device Modeling 3R-3L-4C F,W,S Pre: ECE 204, MA 211

Modeling, analysis, and simulation of electronic circuits that contain two-terminal and three-terminal semiconductor devices. Large-signal, biasing, and small-signal analysis models. Introduction to wave shaping circuits, switching circuits, and amplifiers. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Pre: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,S Pre: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Integral laboratory.

ECE 320 Linear Control Systems 3R-3L-4C W,S Pre: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C W,S Pre: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C F,S Pre: CSSE 232

Pipelining, memory hierarchy, peripherals, parallel processing, cost-performance tradeoffs, and a review of new topics in the areas of computer architecture or parallel processing. Computer use, memos, and discussion of current events.

ECE 333 Digital Systems 3R-3L-4C F,S Pre: ECE 130, ECE 205, ECE 250

Capabilities and limitations of digital CMOS logic devices. Design and evaluation of combinational and sequential logic circuits using Programmable Logic Devices. System integration with multiple components (FPGA, discrete components). CAD tools for design entry, timing simulation, and mapping to target devices. Troubleshooting using laboratory instrumentation. Laboratory notebooks. Informal reports. Integral laboratory.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Pre: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Pre: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,S Pre: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 343 High-Speed Digital Design 3R-3L-4C F,S Pre: ECE 300 and Computer Engineering Major

Signal path modeling through connecting lengths of transmission lines with lumped element models of discontinuities. Circuit parameters from geometries and material properties for resistance, capacitance, inductance and transmission line segments. Lossless and lossy transmission line circuit modeling. High-frequency and high-speed behavior of passive components. Frequency spectrum of digital signals. Digital device

driver and receiver modeling. Transmission line impedance discontinuity and termination techniques. Electric and magnetic field coupling mechanisms for capacitive and inductive crosstalk. Ground noise, power plane noise and resonance. Signal and power integrity issues in high-speed digital systems at both the printed-circuit board and chip levels.

ECE 351 Analog Electronics 3R-3L-4C W,S Pre: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal properties of op-amps. Integral laboratory.

ECE 362 Principles of Design 3R-0L-3C F, S
Pre for EE: ECE160, ECE250, ECE300, ECE340
Pre for CPE: ECE160, ECE250, ECE300
Pre for CS and SE majors: CSSE 374
Pre for ME majors: EM 103, ES 205, and ECE 207

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3R-1L-4C F, S Pre: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, and wind technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C W, S Pre: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C W,S Pre: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Pre: Consent of instructor
Special design or research projects.

ECE 410 Communication Networks 4R-0L-4C S Pre: Senior standing or consent of instructor

Layered architectures. Circuit and packet switching. ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Reliable message transport, internetworking.

ECE 412 Software Defined Radio 4R-0L-4C Pre: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front-end, and clock-jitter of the A/D. As a course project students will design and simulate a complete software-defined radio.

ECE 414 Wireless Systems 4R-0L-4C W Pre: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Pre: Consent of instructor
Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing
Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with CHE 405, EP 410, and ME 416.

ECE 418 Fiber Optic Systems 4R-0L-4C S Pre: ECE 310 or consent of instructor
Analysis and design of common photonic systems such as fiber optic communication links, optical sensing

systems, and optical networks. Topics include basic architectures, component overview, system design, and expected degradations along with mitigation techniques. An oral presentation of a technical paper is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Pre: ECE 320 or ME 406

Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prerequisites: ECE 320 or ME 406, Programming proficiency

This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Pre: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Pre: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Pre: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, W Pre: ECE 362

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W, S

Pre for EE: ECE310, ECE320 ECE333, ECE341, ECE351, ECE370 or ECE371, ECE380, ECE460

Pre for CPE: CSSE332, ECE331, ECE332, ECE333, ECE342, ECE351, ECE380, ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W, S Pre: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Pre: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Pre: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients,

system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Pre: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Pre: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/PH 437 Introduction to Image Processing 3R-3L-4C Pre: MA 212 and Junior standing

Basic techniques of image processing. Discrete and continuous two-dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory. Same as PH 437.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Pre: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Pre: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Pre: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Pre: Consent of instructor

Special design or research projects.

Undergraduate-Graduate Courses

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Pre: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Pre: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor

Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with ME 519, EP 511, and CHE 519.

ECE530 Advanced Microcomputers 3R-3L-4C S Pre: Graduate standing and ECE 331 or ECE 230; or ECE 331 or ECE 230 with a grade of B or better; or consent of instructor

32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software

debugging tools. Integral laboratory.

ECE534 High-Speed Digital Design 4R-0L-4C W Pre: Graduate Standing, or ECE340 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal integrity issues in high-speed digital systems at printed-circuit board (PCB) and chassis levels. Frequency spectrum of digital signals. Frequency behaviors of passive components. Behavior models of drivers and receivers. Transient behaviors of transmission lines. Time-domain reflectometry. Signal reflection and ringing on printed-circuit board. Impedance discontinuity and matching. Load termination techniques. Capacitive and inductive crosstalk. Ground noise. Power plane noise and resonance. High-speed PCB design guidelines. PCB simulation tools.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Pre: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of instructor

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C W Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Wave-guide structures, scattering parameters, passive components, active components, computer-aided design of amplifiers, oscillators and mixers, microwave/millimeter-wave systems, microwave and millimeter-wave integrated circuits.

ECE542 Advanced Electromagnetics 4R-0L-4C F Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, power and energy, material properties, waves, reflections, radiation, EM field theorems, boundary value problems, skin effect.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Pre: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C S Pre: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C S Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Instrumentation amplifiers. A/D and D/A converters. Shock protection. Generation, recording and analysis of biological potentials (ECG, EMG, EEG). Ultrasound techniques and instrumentation. X-ray CAT techniques. Project involving the design of a significant instrument will run throughout the course. No laboratory, but emphasis on computer simulation of the circuits studied.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C S Pre: Graduate standing and ECE 351; or ECE 351 with a grade of B or better; or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE 557 Analog Test and Product Engineering 3R-3L-4C F Pre: Graduate standing and ECE 300 and ECE 351; or ECE 300 and ECE351 with grades of B or better in both courses; or consent of instructor

Fundamental skills necessary to be an industrial integrated circuit test engineer or product engineer. Includes the economics associated with testing, impact of fabrication variation on devices, instrumentation associated with industrial testing, turning a data sheet into a test plan, industrial testing techniques for analog circuits, trade-offs between test time and test accuracy, statistical analysis of the data and statistical process control, the use of device interface boards necessary to control device loading for different tests. Integral labs with an industrial grade automatic tester (ATE).

ECE580 Digital Signal Processing 4R-0L-4C W Pre: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Pre: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE 582/PH 537 Advanced Image Processing 3R-3L-4C Pre: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as PH 537.

ECE 583 Pattern Recognition 3R-3L-4C S Pre: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 597 Special Topics in Electrical Engineering 4C Pre: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C arranged

Thesis topic selected in consultation with adviser. Graduate students only.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Management

Professors Downing, Kline, Schumacher and Stamper

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4C

Pre: Junior, Senior, or consent of instructor

Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC

Pre: MG 461 or consent of instructor

Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC

Pre: MG 462 or consent of instructor

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C, Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT511 Graduate Seminar I 1R-0L-1C F

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT512 Graduate Seminar II 1R-0L-1C W

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT513 Graduate Seminar III 1R-0L-1C S

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT514 Graduate Seminar IV 1R-0L-1C Summer

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT520 Accounting for Technical Managers 4R-0L-4C - Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C, Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership, Change and Organizational Culture 4R-0L-4C - Management

Review of fundamental activities (planning, organizing, leading, controlling) related to the management of organizations. The concepts and techniques for maximizing the effectiveness of human resources in the achievement of organizational and project goals are emphasized. Topics include communication, team process, motivation, selection, development, and appraisal. Special focus is given to the management of human resources in a technical environment.

EMGT523 Marketing in New Product Development 4R-0L-4C, - Management

A study and overview of the components of marketing principles and how those mesh with management in a technical environment. Topics will include activities associated with product, price, promotion, and distribution and how these impact the technical manager from idea generation through delivery to and service for the customer.

EMGT524 Production/Operations Management 4R-0L-4C, Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-0L-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-0L-4C

This course introduces the concepts of innovation types (radical, incremental, disruptive) and patterns of

technology evolution. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy use, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, expert judgment (Delphi), road-mapping and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-0L-4C - Technical or Management

Addresses the major issues and techniques of project management, including team building, project evaluation and selection, scheduling techniques, quality management, development of negotiation and conflict management skills. Also examines project management success factors. Uses a large scenario planning exercise and several case studies to illustrate course content. Can be used as part of the technical or management core.

EMGT531 Economics for Technical Managers 4R-0L-4C - Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C - Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C - Management

The core of this course is the presentation of the Constructivist theory of communication and its application. Students are exposed to ethnographic interview methods and the concept of culture shock using the BAFA role-play simulation. Discussion of organizational culture includes a review of publications on this topic, the impact of culture on organizations, as well as strategies for change. May be used as a management core class.

EMGT534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing Technical or Management

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-0L-4C, Management

Reviews the strategy literature and the issues surrounding strategy implementation in the context of organizational change. Includes a team project that explores the strategic implications of globalization for specific industries during the next 10 years and the construction of scenarios as a tool for understanding and communication. Individual students will develop and evaluate strategy for a specific organization within the scenarios developed in the team project.

EMGT540 Fundamentals of Engineering Management 4R-0L-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT 551 Intellectual Property for Engineers and Scientists 4R-0L-4C Technical or Management Elective

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-0L-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C, Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization. Cross-listed with EMGT 486.

EMGT587 Systems Engineering 4R-0L-4C, Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C - Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Pre: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and

other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.



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Course Descriptions

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Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Engineering Mechanics

EM403 Advanced Mechanics of Materials 4R-0L-4C S Pre: EM 203 or EM 204
Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

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|--|
| Aerospace Studies (Air Force ROTC) |
| Applied Biology & Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| College & Life Skills |
| Computer Science & Software Engineering |
| Electrical & Computer Engineering |
| Engineering Management |
| Engineering Mechanics |
| Engineering Physics |
| Geology |
| Humanities and Social Sciences |
| Mathematics |
| Mechanical Engineering |
| Military Science (Army ROTC) |
| Multi-Disciplinary Studies |
| Optical Engineering |
| Physics |
| Robotics |
| Sophomore Engineering |

EM 406 Vibration Analysis 4R-0L-4C F Pre: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

Undergraduate-Graduate Courses

***EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Pre: ME401 or consent of instructor**

Course may be repeated for different topics in fluid mechanics.

***EM 502 Advanced Dynamics 4R-0L-4C Pre: ES 205**

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

***EM 503 Advanced Vibration Analysis 4R-0L-4C W Pre: EM 406**

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.


***EM 505 Theory of Elasticity 4R-0L-4C Pre: EM 203 or EM 204**

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

***EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Pre: EM 403 and MA 330**

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.

*May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.



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Course Descriptions

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Letfullin, McInerney, Moloney, Siahmakoun, Sirohi, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W Pre: PH113

Scaling laws in small systems, basics of quantum mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, nanomechanics, cantilever oscillation, atomic-force microscope (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors.

EP 290 Directed Study Credit arranged Pre: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S Pre: EP280

Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, nanoscale heat: conduction, convection, and radiation. Nanophotonics in metals and semiconductors, surface Plasmon resonance and applications, photonic bandgap crystals, basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise. Cross-listed with EP 506.

EP 408 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Pre: EP 410 or equivalent course

Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-listed with ECE 419, and CHE 419.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

EP 415 Engineering Physics Projects I 4C S Pre: RH 330 and consent of the instructor

Team-oriented and/or independent design project work on selected topics in any engineering discipline but related to concepts to strengthen both the application and physics and engineering, design of project, building of prototype, experiments to test components and systems, and market analysis. Cross-listed with OE 415.

EP 416 Engineering Physics Projects II 4C F Pre: Consent of the instructor

Follow up course to EP415. To be taken as a sequence from the same department where EP415 was taken. Cross-listed with OE 416.

EP 417 Engineering Physics Projects III 2R-6L-4C W Pre: Consent of the instructor

Follow up course to EP416. To be taken as a sequence from the same department where EP415 and EP416 were taken. Cross-listed with OE 417.

EP 470 Special Topics in Engineering Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 406.

EP 508 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Pre: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.



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quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art	Anthropology
English and Literature	Economics
Foreign Languages(German, Japanese, and Spanish)	Geography
History	Political Science
Music	Psychology
Philosophy and Religion	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- Global Studies (GS prefix): Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- Ideas and Arts (IA prefix): Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.
- Society and Values (SV prefix): Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communications are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communications is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general lower level courses (100 and 200 level) tend to be broad surveys of particular subject areas within disciplines. Upper level courses (300 and 400 level) are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General

- All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

- All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted free elective transfer credit, but are not exempted from RH 131.
- EXEMPTION: An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. Any HSS course may be substituted for RH 131 for exempted students.
 1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.
 2. Has received grades of B or higher in all high school English courses.

3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.
 1. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.
 2. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three thematic categories as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each thematic category in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
 3. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
 4. Students may not earn foreign language credit in their native languages.
 5. Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. Minors

- Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

HELP WITH REQUIREMENTS

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, or Spanish, by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

Minor	Advisor
Anthropology	Scott Clark
Art	Steve Letsinger
East Asian Studies	Huei-Ying Kuo
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter
Geography	Michael A. Kukral

History	Samuel Martland
Japanese	Maki Hirotani
Language and Literature	Caroline Carvill
Music	Gary Turner
Latin American Studies	Gustavo Garcia
Philosophy and Religion	Heinz Luegenbiehl
Political Science	Terrence Casey
Psychology	Patrick D. Brophy
Spanish	John Gardner

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Introduction to East Asian History 4R-OL-4C

Examine the changing political-economic and cultural orders in the East Asian region (including China, Japan, and Korea) from imperial to modern era.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Asian Religions and Philosophy 4R-OL-4C

Focuses on the thought systems of India, China, and Japan. Discusses Hinduism, Buddhism, Confucianism, Taoism, and Shinto.

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History 4R-OL-4C

Explores the history and interaction of major world regions, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction's humanistic usefulness in examining human values from an "extra-species, extra-terrestrial" perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 285 Humans and Culture 4R-OL-4C

Examines human adaptation and diversity; language and its use; the development and variety of economic, political, religious, family gender and expressive institutions.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS330 Contemporary Global Film 3R-3L-4C.

Examines films outside of the Hollywood tradition with a consideration of the cultural, political, and economic influences that shape film.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 350 International Trade and Globalization 4R-OL-4C Pre: SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Pre: SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Pre: SV 151

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 363 European Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of selected European political systems.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Contemporary Japan (Field trip to Japan) 4R-OL-4C

Examine contemporary Japan through the lectures, reading, and discussions during the course. Explorer the culture through the field trip to Japan.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 384 Japanese Society 4R-OL-4C

Examines the context within which individual Japanese live and work in contemporary Japanese society. Considers the “traditional” roots of Japan, the impact of industrialization, and current trends. Emphasizes the change and continuity in Japanese life, including the family and marriage, rural and urban lifestyles, education, and the organization of management and labor.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS425 Cities and Technology in the Industrial Age 4R-OL-4C

Explores development of cities and the machines and systems that make them possible as human life became more and more urban and industrial from 1700 to the present. Compares urban growth and city life in different parts of the world.

GS430 World Drama 4R-OL-4C

Examines drama from multiple cultures and time periods through a thematic lens.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS470 Japanese Media 4R-OL-4C

Explores historical and contemporary media-related Japanese culture, both in visual and text communications.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

Ideas and Arts -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R-OL-4C

Introduces the student to the methods and subject matter of philosophy through a selective consideration of fundamental philosophical problems such as the nature of reality, the existence of God, the criteria of knowing, and the basis of morality.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Jane Austen and the Rhetoric of Fiction 4R-OL-4C

Provides a guide to reading, appreciating, and analyzing Jane Austen's major novels. Analyzes a variety of film adaptations, comparing them to the novels in their rhetorical effects.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 3R-3L-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Concepts 4R-OL-4C

Teaches basic techniques of music notation and analysis of melody, harmony, rhythm, form, and style. Includes a comprehensive Analysis Project.

IA 302 Philosophy of Religion 4R-OL-4C

Examines the basic philosophical problems found in religion. Deals specifically with the nature of religion, the nature and existence of God, religious language, and the religious life.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 330 Documentary Film 3R-3L-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA338 Medicine in Literature 4R-OL-4C

Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA340 Ethics in Human Communication 4R-OL-4C

Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 346 Music Theory II: Applications 4R-OL-4C Pre: IA246 or consent of instructor

Applies notational and analytical techniques to arranging/composing tasks, using music notation software.

IA 348 Music Performance 1R-OL-1R Pre: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C Pre: SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C Pre: SV 151

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Pre: SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C Pre: SV 151

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Pre: SV 151

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Pre: SV 151

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

IA 471 Literature of Madness 4R-OL-4C

Analyzes the literary, biographical, and scientific relationships between artistic and manic-depressed temperaments. Examines how "great wits and madness" relate.

Society and Values -- Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 151 Principles of Economics 4R-OL-4C

Includes both microeconomics and macroeconomics. Analyzes market behavior. Considers production and pricing decisions under alternative industrial structures. Examines the determinants of economic growth, unemployment and inflation, including fiscal and monetary policy.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

Surveys learning, motivation, personality, intelligence, abnormal behavior, social behavior, perception, emotion, and psychobiology. Stresses objective analysis of behavior and provides a foundation for advanced courses.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 200 Career Preparation 1R-OL-1C W,S

This course is for economics majors, to be taken in the second or third year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resume

preparation. Cross-listed with CHEM200, and MA200.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV 244 Music History: Medieval, Renaissance, Baroque 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 245 Music History: Classical, Romantic, Modern 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 272 Experimental Psychology 4R-OL-4C

Emphasizes experimental analysis of perception, motivation, learning, and personality. Programmed and independent experiments are performed. Laboratory periods are arranged.

SV 288 Introduction to Sociology 4R-OL-4C

Examine the social and historical construction of our personal identity based on race, class, and gender as well as how social and global inequality is associated with these categories.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R-OL-4C

Examines the ethical issues faced by professional engineers in the global corporate context. Deals with such topics as codes of ethics, professional autonomy, employer authority, and whistle blowing.

SV 304 Bioethics 4R-OL-4C

Introduces students to basic issues in bioethics such as physician-patient relationships, the conduct of research, cross-cultural concerns, and codes of ethics.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies

have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 350 Managerial Accounting 4R-OL-4C Pre: SV 151

Covers accounting concepts and procedures for preparation of financial reporting. Emphasizes use of accounting as a tool for management control and decision making.

SV 351 Managerial Economics 4R-OL-4C Pre: SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. In addition to SV 151, students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Pre: SV 151

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Pre: SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Pre: SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Pre: SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Pre: SV 151

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Pre: SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 373 Gender Issues4R-OL-4C

Examines male-female differences in behavior, personality, emotion, and cognition. Examines how men and women differ as they pursue the goals of life and the degree to which these differences are innate or learned.

SV 375 Personality Theories4R-OL-4C

Presents an organized summary of major contemporary theories of personality. Compares and contrasts theories of human behavior. Analyzes the degree that behavior is purposive, unconscious, instinctive, learned, modifiable, and predictable.

SV 382 Anthropology of Religion 4R-OL-4C

Examines various concepts and practices pertaining to the supernatural, focusing primarily on indigenous religions around the world. Discusses the relationships of religious beliefs, values, and practices with social organization, economic behavior, subsistence systems, and technology

SV 385 Archaeology & Prehistory 4R-OL-4C

Examines the human past through the analysis of cultural artifacts: the course focuses on the methods and techniques of archaeology and the study of the major cultural and social transformations from foraging to agricultural and complex civilizations.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and ongoing evolution: examines the evidence of the fossil record and genes, compares human behavior with other primates, considers physical basis for behaviors, and the extent and causes of human physical diversity..

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C Pre: SV 151

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

Communication

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis ofttexts and images,research methods, and theconventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Pre: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

Special Topics and Directed Study

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS

Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX496 Seminar for HSS Senior Project 2R-OL-2C F Pre: Economics or International Studies major and

Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX497 Directed Study for HSS Senior Project 2R-OL-2C Arranged Pre: XX496 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double majors.

Modern Languages

Note: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Pre: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Pre: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Pre: GE 213

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Pre: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C Summer Pre: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in

engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Pre: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-OL-4C S

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-XL-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

HSS Majors

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning OutComes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 - A. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 - B. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 - C. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 - A. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 - B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 - A. Assemble and evaluate resources for research in international studies.
 - B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the

IPE area of concentration.

- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA233 World Literature
GS163International Relations
GS285Humans and Culture
GS291World Geography
SV151 Principles of Economics
GS223World History

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

- a. International Political Economy: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose at least three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General List

IA353 History of Economic Thought
GS322Industrial Revolution in a Global Context
GS350International Trade and Globalization
GS351International Finance
GS352Economic Growth and Development
GS361Politics of the Global Economy
SV328 Comparative Business History
SV354 Environmental Economics

Regional List

GS128Introduction to East Asia
GS161Comparative Politics
GS222Modern Latin American
GS366European Union
GS363European Politics and Government
GS399Geography of the Middle East
GS492Geography of Africa

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

- a. Comparative Cultures: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322Industrial Revolution in Global Context
GS333Travel in World Literature
GS334Global Novel in the 20th Century
GS432Literature of the Global Economy
GS462Postcolonial Literature
SV191 Cultural Geography
SV201 Religion and Ecology
SV226The West in the East
SV382Anthropology of Religion

Regional list (including but not limited to the following courses)

- IA311 Topics in German Culture I
- GS128Introduction to East Asia
- GS207Asian Religions and Philosophy
- GS222Modern Latin America
- GS313Contemporary Spain
- GS327Modern China
- GS335Arabic Literature
- GS379Japanese Culture
- GS391Contemporary Europe
- GS442Art History: Reniassance to Modern
- GS492Geography of Africa

1. Individualized Major: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS Minors

Minor in Anthropology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

1. Five Courses in Anthropology.
 2. The following three courses are required:
 - GS 285 Humans & Culture
 - SV 385 Archaeology & Prehistory
 - SV 386 Human Evolution
- A minimum of 40 credits in HSS courses must be earned to obtain the minor.
 - Substitutions may be made with the approval of the Minor Advisor
- Courses
- GS 384 Japanese Society
 - SV 382 Anthropology of Religion
 - XX 399 Special Topics
 - XX 499 Directed Study

Minor in Art

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

1. Five Courses in Art:
 - a. The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242
 2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
 3. Substitutions may be made with the approval of the Minor Advisor
- Courses
- GS442 Art History: Renaissance to Modern
 - IA142 Drawing

- IA148 Beginning Photography
- IA244 Design and Color
- SV242 Visual Arts in Civilization

Minor in East Asian Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS128 Introduction to East Asian History
 - GS207 Asian Religions and Philosophy
 - GS324 Gender and Work in China
 - GS327 Modern China
 - GS384 Japanese Society
 - SV226 The West in the East
 - SV326 Overseas Chinese
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Economics

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Principles of Economics (SV 151);
 - b. Intermediate Microeconomics (IA 350) or Intermediate Macroeconomics (IA 351);
 - c. Three additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- GS350 International Trade and Globalization
- GS351 International Finance
- GS352 Economic Growth and Development
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- IA352 Game Theory
- IA353 History of Economic Thought
- IA450 Mathematical Economics
- IA453 The Entrepreneur
- SV151 Principles of Economics
- SV350 Managerial Accounting
- SV351 Managerial Economics
- SV352 Money and Banking
- SV353 Industrial Organization
- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX499 Directed Study

Minor in European Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - o GS313 Contemporary Spain
 - o GS337 Shakespeare's Europe
 - o GS363 European Politics and Government
 - o GS366 The European Union
 - o GS431 Literary London
 - o GS469 Contemporary British Fiction and Film
 - o GS491 Geography of Europe
 - o IA311 Topics in German Culture I
 - o IA337 European Romanticism
 - o SV222 Western Civilization to 1500
 - o SV223 Western Civilization from 1500 to the Present
 - o SV291 Medieval Europe
 - o SV413 Contemporary Germany
 - o XX399 Special Topics
 - o XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Geography

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- o GS191 Geography of Middle East
- o GS222 Modern Latin America
- o GS291 World Geography
- o GS327 Modern China
- o GS391 Contemporary Europe
- o GS491 Geography of Europe
- o GS492 Geography of Africa
- o SV191 Cultural Geography
- o SV291 Medieval Europe
- o XX399 Special Topics
- o XX499 Directed Study

Minor in History

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- o GS128 Introduction to East Asian History
- o GS221 Colonial Latin America
- o GS223 World History

GS222 Modern Latin America

- GS324 Gender and Work in China
- GS327 Modern China
- GS422 Industrial Revolution in Global Context
- IA388 Chinese Nationalism
- SV222 Western Civilization to 1500
- SV223 Western Civilization since 1500
- SV226 The West in the East
- SV322 Disasters and Modern Society since 1700
- SV326 Overseas Chinese
- SV328 Comparative Business History
- SV329 Cities in Latin American History
- XX399 Special Topics
- XX499 Directed Readings

Minor in Language and Literature

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and HS330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS237 Science Fiction
- GS334 Travel in World Literature
- GS335 The Global Novel in the Twentieth Century
- GS336 Literature of War
- GS337 Shakespeare's Europe
- GS338 Contemporary Arabic Literature in Translation
- GS412 Topics in German Culture II
- GS431 Literary London
- GS432 Literature and Film of the Global Economy
- GS462 Postcolonial Literature
- GS469 Contemporary British Fiction and Film
- IA230 Fundamentals of Public Speaking
- IA231 Introduction to Poetry
- IA232 African American Music in American Literature
- IA233 World Literature
- IA234 Major American Writers
- IA236 Jane Austen and the Rhetoric of Fiction
- IA237 Introduction to Drama
- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature
- IA337 European Romanticism
- IA339 Rebellion in American Literature
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Masculinity and Work in Fiction and Film

- SV334 Utopian Thought and Literature
- SV336 Contemporary American Fiction
- SV337 20th century American Novel
- SV339 Literature and the Environment
- SV234 The American Dream
- XX399 Special Topics
- XX499 Directed Study

Minor in Latin American Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS221 Colonial Latin America
 - GS222 Modern Latin America
 - GS323 The Andean Countries of South America
 - GS313 Contemporary Spain
 - IA332 Don Quixote
 - SV329 Cities in Latin American History
 - SV338 Latin American Fiction: The Boom and Beyond
 - XX399 Special Topics
 - XX499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Modern Languages (German, Japanese, and Spanish)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture IV/V/VI
SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413
Japanese Language and Culture X/XI/XII

XX 399 Special Topics
XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless

the second course in the sequence is also completed successfully.

Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

Minor in Music

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. A minimum of 40 credits must be earned to obtain the minor. 36 of these credits must be in HSS courses. The remaining four (4) credits may be in an approved course from outside the HSS Department.
2. The following four courses are required:
 - o SV244 Music History: Medieval, Renaissance, Baroque
 - o SV245 Music History: Classical, Romantic, Modern
 - o IA246 Music Theory I: Concepts
 - o IA346 Music Theory II: Applications

To fulfill the fifth course requirement for the Area Minor in Music, the candidate may choose ONE of the following options:

- a. A course from outside the HSS Department, approved by the Minor Advisor, such as:
 - o ECE481 Electronic Music Synthesis
 - o PH404 Acoustics
 - o PH460 Directed Study (music-related)
- b. IA 499: Directed Study in Music. Pre-requisite: consent of the Minor Advisor.
- c. A 348: Music Performance. Pre-requisite: consent of the Minor Advisor.
- d. Four (4) credits of Satisfactory participation in one or more of the formal Performing Groups (Concert Band, Jazz Ensemble, String Ensemble, and Chorus) are required. Performance credit may not be transferred from another college. One academic term of satisfactory participation earns one credit. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for "satisfactory participation" will be provided to the candidate by the Minor Advisor.

Minor in Philosophy and Religion

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy and Religion has the following requirements:

1. Five courses in Philosophy and Religion, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- o GS207 Asian Religions and Philosophy
- o IA101 Introduction to Philosophy
- o IA302 Philosophy of Religion
- o IA335 Bible as Literature
- o SV201 Religion and Ecology
- o SV303 Business and Engineering Ethics
- o SV304 Bioethics
- o SV382 Anthropology of Religion
- o XX399 Special Topics
- o XX499 Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International

Relations (GS 163), or American Politics and Government (SV 166)

2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS161 Comparative Politics
- GS163 International Relations
- GS361 Politics of the Global Economy
- GS366 The European Union
- GS363 European Politics and Government
- SV166 American Politics and Government
- SV369 British Politics and Government
- SV463 Seminar on America's Future
- XX399 Special Topics
- XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Five courses in Psychology, distributed as follows:
 - Principles of Psychology (SV 171).
 - Experimental Psychology (SV 272).
 - Three other Psychology courses.
2. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Courses

- IA471 Literature of Madness
- SV171 Principles of Psychology
- SV272 Experimental Psychology
- SV375 Personality Theories
- SV373 Gender Issues
- XX399 Special Topics
- XX499 Directed Study

German Technical Translator's Certificate Program

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute's degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).


Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-

Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60



Rose-Hulman
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Terre Haute, IN 47803
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Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Mathematics

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Pre: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.

A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen. Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

Covers approximately the first half of MA 111, including analytic geometry in the plane, algebraic and transcendental functions, limits and continuity, and an introduction to differentiation. Entering first-year students will enroll in MA 111 and transfer to MA 101 if continuation of MA 111 is not appropriate.

Covers approximately the second half of MA 111, including the derivative, geometrical and physical applications of differentiation, and an introduction to integration and Fundamental Theorem of Calculus. Students who do not transfer to MA 101 in the fall quarter, but do not satisfactorily complete all of MA 111, may use their midterm grade in MA 111 for credit and grade in MA 101 and enter MA 102 at the beginning of the winter quarter.

Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and applications, famous problems, and outstanding problems of great significance.

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| Aerospace Studies (Air Force ROTC) |
| Applied Biology & Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| College & Life Skills |
| Computer Science & Software Engineering |
| Electrical & Computer Engineering |
| Engineering Management |
| Engineering Mechanics |
| Engineering Physics |
| Geology |
| Humanities and Social Sciences |
| Mathematics |
| Mechanical Engineering |
| Military Science (Army ROTC) |
| Multi-Disciplinary Studies |
| Optical Engineering |
| Physics |
| Robotics |
| Sophomore Engineering |

MA 200 Career Preparation 1R-0L-1C W,S

This course is for mathematics and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200, and SV200.

MA 211 Differential Equations 4R-0L-4C F, W, S Pre: MA 113

First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F, W, S Pre: MA 113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F, W, S Pre: MA 112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Pre: MA 112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Pre: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arr Pre: CSSE 220 or CSSE221, and MA 212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W, (odd years) Pre: MA 113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F Pre: MA 113

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F Pre: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C S Pre: MA 211, MA 212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Pre: MA 211, MA 212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA 342 Computational Modeling 4R-0L-4C S Pre: MA 212 and one of CHE 310,CE 310,MA 332 or ME 323

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 348 Continuous Optimization 4R-0L-4C S (even years) Pre: MA 212

Optimization of nonlinear functions of real variables: algorithms for univariate optimization; Golden section, parabolic interpolation, hybrid methods; Newton's Method and variations for multivariate functions; conjugate gradients and quasi-Newton methods; line search strategies; penalty functions for constrained optimization; modeling and applications of optimization.

MA 351-6 Problem Solving Seminar 1R-0L-1C F, W, S Pre: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Pre: MA 275 and MA 113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Pre: MA 212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Pre: MA 212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Pre: MA 212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Pre: MA 275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Pre: MA 275

An introduction to modern abstract algebra and algebraic structures. Topics include congruence and modular

arithmetic; rings, ideals, and quotient rings; fields, finite fields, and subfields; groups and subgroups; homomorphisms and isomorphisms. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Pre: consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F, W, S Pre: MA 113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C (F) Pre: MA 381

This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the central Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Pre: MA 223 or MA 382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Pre: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary.

MA 386 Statistical Programming 4R-0L-4C Pre: previous programming course and either MA 223 or MA 382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Pre: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 390 Topics in the Mathematics of Engineering 1-2C (arranged) Pre:consent of instructor

A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

MA 421 Tensor Calculus and Riemannian Geometry 4R-0L-4C (arranged) Pre: MA 330

An introduction to the calculus of tensor fields and the local geometry of manifolds. Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

MA 423 Topics in Geometry 4R-0L-4C (arranged) Pre: MA371 or MA373 or consent of instructor

An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C (arranged) Pre: instructor permission

A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C (arranged) Pre: MA 330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to "direct methods." Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Pre: MA 212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C (arranged) Pre: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 435 Finite Difference Methods 4R-0L-4C W Pre: MA 332 or MA 371 or MA 373 or MA 433

An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Pre: MA 330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green's function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Pre: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Pre: MA 212 and one of MA 371 or MA 373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development "from the ground up."

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Pre: MA 223 or MA 381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Pre: MA 375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F, W, S Pre: consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based

on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C (arranged) Pre: MA 366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view.

Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C (arranged) Pre: MA 366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Pre: MA 371 or MA 373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Pre: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Pre: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C (arranged) Pre: MA 375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Pre: MA 375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Pre: MA 375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C (arranged) Pre: MA 378 or MA 375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Pre: CSSE 220 and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C (arranged) Pre: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Pre: MA 382, or MA 381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Pre: MA 223 or MA 382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Pre: MA 212 and either MA 223 or MA 382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Pre: MA 223 or MA 382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics, variable credit, Pre: consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Pre: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Pre: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F, W Pre: MA 492 or permission of the instructor

MA 494 Senior Project III 2C W, S Pre: MA 493

Participation in sponsored projects or problems with a substantial mathematical and/or computational content. Students typically work in teams of at most 3, with appropriate faculty supervision. Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of Senior Project must be completed in a form acceptable to the sponsor and the advisor.

MA 495 Research Project in Mathematics, variable credit, Pre: consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Pre: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Pre: MA 496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Pre: MA 497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C (arranged) Pre: MA 381


Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C (arranged) Pre: MA 223 or MA 381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Pre: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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Graduate Studies

Mechanical Engineering

Professors Adams, Bernal, Brackin, Burchett, Chambers, Cornwell, Cunningham, Fine, Fisher, Gibson, Haan, Jones, Kawano, Layton, Lui, Mayhew, Mech, Moorhead, Moseley, Olson, Onyancha, Purdy, Richards, Sanders, Stamper, Stienstra, Toohey, and White.

ME 123 Computer Applications I 4R-0L-4C W,S Pre: None

Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion (Working Model), presentation software (Powerpoint, HTML), and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S

Selected student design projects. May include testing and/or computer aided design.

ME 201 Thermodynamics I 4R-0L-4C F Pre: MA 112

Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Sophomore class standing

Selected student design projects. May include testing and/or computer aided design.

ME 301 Thermodynamics II 4R-0L-4C F,W Pre: ES 202 or ME 201

Applies property and component background to the analysis of various power and refrigeration cycles. Presents gas and gas-vapor mixtures, psychometric processes, and combustion. Introduces compressible flow.

ME 302 Heat Transfer 4R-0L-4C S,F Pre: MA 211 and ES 202 or CHE 301 or EM 301

Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Pre: ES 202

Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Pre: EM 104

This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Pre: ME 328

An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Pre: ECE 207, ES 205, MA 223

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Computer Applications II 1R-3L-2C W,S Pre: ME 123, or CSSE 120, MA 212

Introduction to structured programming and applied numerical methods in scientific computing. The course uses applied problems in engineering and mathematics to introduce numerical methods such as numerical interpolation, finite differencing, integration, root finding, and linear algebraic system solutions. Matlab is taught as a vehicle for solving the problems numerically in a structured high speed environment.

ME 328 Materials Engineering 4R-0L-4C W Pre: CHEM 111

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Pre: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

***ME 401 Foundations of Fluid Mechanics 3R-3L-4C Pre: ES 202 or EM 301, MA 212**

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective*

***ME 402 Advanced Heat Transfer 4R-0L-4C Pre: ME 302**

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 403 Kinematics of Machinery 4R-0L-4C Pre: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

***ME 405 Theoretical Aerodynamics 4R-0L-4C F Pre: ES 202**

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 406 Control Systems 3R-3L-4C F Pre: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Pre: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are

taken when available.

ME 408 Renewable Energy 4R-0L-4C Pre: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C F Pre: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Pre: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Pre: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Pre: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 410, ECE 416, and CHE 405.

***ME 417 Advanced Materials Engineering 4R-0L-4C Pre: ME 328 and EM 203 or EM 204**

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ECE 466, CHE 420, and CE 420.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Pre: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

***ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Pre: EM204**

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Pre: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team

design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Pre: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Pre: ES 205 or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

***ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Pre: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 430 Mechatronic Systems 3R-3L-4C F,W Pre: (ME 323 or CSSE 220 or ECE 230) and (ECE 207 or ECE 204) or consent of instructor

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

***ME 435 Robotics Engineering 3R-3L-4C S Pre: ME 430 and Senior class standing**

Interdisciplinary course in engineering systems applied to computer controlled automata. Topics include kinematics, control, operation, sensing, and design as applied to various types of industrial and other robots and programmable manipulators. A related project is required.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 450 Combustion 4R-0L-4C Pre: ME 301**

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises.

**May be used to satisfy Mechanical Engineering requirement for an advaced technical elective.*

ME 461 Aircraft Design 4R-0L-4C W Pre: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams.

ME 462 Thermal Design 4R-0L-4C W,S Pre: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Engineering Design Processes and Methodology 2R-3L-3C F,S Pre: 3rd qtr junior standing

Design of multi-component systems with consideration of societal and economic factors. Useful design techniques (such as modeling, CPM, optimization, probabilistic approaches, etc.) and factors influencing design (such as human factors, products liability, ethics, safety, etc.) are presented and discussed. Laboratory assignments emphasize case studies. (Students completing ME470 may not receive credit for EMGT 461.)

ME 471 Capstone Design I 1R-6L-3C W Pre: ME 470, ME 480

Design projects with industry. Students work in teams with three or four members on design projects furnished from external clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in oral presentations and Interim Written Reports which are submitted to the clients.

ME 472 Capstone Design II 1R-6L-3C S Pre: ME 471

This course is a continuation of ME 471. The student teams continue their design solutions to a general problem furnished by an external client. Continuous and regular communication with the outside clients is expected, as well as with the faculty advisors. During these ten weeks the teams continue refining their solutions, complete the detail design, make oral presentations of the final design, and complete and submit the Final Written Report.

ME 480 Machine Component Design 4R-0L-4C S & F Pre: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor

Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Senior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged

Topics of current interests in mechanical engineering.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

***ME 501 Advanced Thermodynamics 4R-0L-4C F Pre: ME 301 or equivalent**

Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Pre: ME 302**

Course may be repeated for different heat transfer topics.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 503 Viscous Fluid Flow 4R-0L-4C Pre: ME 401**

Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Pre: ES 205, MA 212**

Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 506 Advanced Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**

Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 507 Applied Nonlinear Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**

Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liapunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 510 Gas Dynamics 4R-0L-4C F Pre: ES 202**

Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..*

***ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Pre: ES 205 and ME 323**

Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 512 Light Weight Structures 4R-0L-4C S Pre: MA 212 and EM 203 or EM 204**

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 513 Environmental Noise 4R-0L-4C F Pre: Senior class standing**

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

***ME 518 Advanced Kinematics 4R-0L-4C S Pre: ME 403**

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Cross-listed with ECE 519, EP 511, and CHE 519.

***ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Pre: EM 104 and Senior class standing**

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 522 Advanced Finite Element Analysis 4R-1L-4C S Pre: ME 422**

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 526 Turbomachinery 4R-0L-4C Pre: ES 205 or equivalent, or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency. Students enrolled in ME 526 must complete a design project including complexities not covered in ME 426. Students may not receive credit for both ME 426 and ME 526

***ME 527 Computational Fluid Dynamics 3R-3L-4C Pre: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution. Students enrolled in ME527 must complete a design project not covered in ME 427. Students may not receive credit for both ME 427 and ME 527.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 536 Computational Intelligence in Control Engineering 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**

Machine learning and adaptation applied to feedback control, guidance and navigation. Neural Networks for pattern recognition, modeling and control. Radial basis function model identification by recursive least squares. Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.
**May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 550 Combustion 4R-0L-4C Pre: ME 301**

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises. Students enrolled in ME 550 must complete a design project not covered in ME 450. Students may not receive credit for both ME 450 and ME 550
**May be used to satisfy Mechanical Engineering requirement for an advaced technical elective.*

***ME 590 Thesis Research F,W,S**

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.
** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S**

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..*



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Course Descriptions

Programs of Study

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Minors

Special Programs

Advanced Placement

Graduate Studies

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Military Science (Army ROTC)

LTC Freidhoff and MSG Zoleske

Freshman Year - Basic Course

MS 101: Leadership and Personal Development 1R-3L-1C F Pre : None

MS 101 introduces cadets to the personal challenges and competencies that are critical for effective leadership. Cadets learn how the personal development of life skills such as critical thinking, goal setting, time management, physical fitness, and stress management relate to leadership, officership, and the Army profession. The focus is on developing basic knowledge and comprehension of Army leadership dimensions while gaining a big picture understanding of the ROTC program, its purpose in the Army, and its advantages for the student.

MS 102: Introduction to Tactical Leadership 1R-3L-1C W Pre: MS 101 or Instructor Permission

MS 102 overviews leadership fundamentals such as setting direction, problem-solving, listening, presenting briefs, providing feedback, and using effective writing skills. Cadets explore dimensions of leadership values, attributes, skills, and actions in the context of practical, hands-on, and interactive exercises. Continued emphasis is placed on recruitment and retention of cadets. Cadre role models and the building of stronger relationships among the cadets through common experience and practical interaction are critical aspects of the MS 102 experience.

MS 103: Basic Tactical leadership 1R-3L-1C S Pre: MS 101 and 102 or Instructor Permission

MS 103 continues the exploration of leadership fundamentals and examines the leadership process as affected by individual differences and styles, group dynamics, and personality behavior of leaders. Students will experience an introduction of fundamental leadership concepts, and examine factors that influence leader and group effectiveness. Students will fully explore the basic soldier skills and squad level tactical operations. Students participate in briefings and hands-on practical exercises. Attention is devoted to development of leadership potential through practical exercises both in and out of the classroom.

Sophomore Year - Basic Course

MS 201: Innovative Team Leadership 2R-3L-2C F Pre: MS 101, 102, and 103 or Instructor Permission

MS 201 explores the dimensions of creative and innovative tactical leadership strategies and styles by examining team dynamics and two historical leadership theories that form the basis of the Army leadership framework. Cadets practice aspects of personal motivation and team building in the context of planning, executing, and assessing team exercises and participating in leadership labs. Focus is on continued development of the knowledge of leadership values and attributes through an understanding of Army rank, structure, and duties and basic aspects of land navigation and squad tactics. Case studies provide tangible context for learning the Soldier's Creed and Warrior Ethos as they apply in the contemporary operating environment (COE).

MS 202: Foundations of Tactical Leadership 2R-3L-2C W Pre: MS 201 or Instructor Permission

MS202 examines the challenges of leading tactical teams in the COE. The course highlights dimensions of terrain analysis, patrolling, and operation orders. Further study of the theoretical basis of the Army leadership framework explores the dynamics of adaptive leadership in the context of military operations. Cadets develop greater self awareness as they assess their own leadership styles and practice communication and team building skills. COE case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Pre: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Leaders' Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Leaders' Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

Junior Year - Advanced Course

MS 301: Adaptive Team Leadership 3R-3L-4C F Pre: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 challenges cadets to study, practice, and evaluate adaptive leadership skills as they are presented with challenging scenarios related to squad tactical operations. Cadets receive systematic and specific feedback on their leadership attributes and actions. Based on such feedback, as well as their own self-evaluations, cadets continue to develop their leadership and critical thinking abilities. The focus is developing cadets' tactical leadership abilities to enable them to succeed at ROTC's summer Leadership Development and Assessment Course (LDAC).

MS 302: Leadership Under Fire 3R-3L-4C W Pre: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when under fire are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Leader Development and Assessment Course (LDAC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Pre: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for LDAC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

**Overview of LDAC: Leader Development and Assessment Course
Summer Term Only**

LDAC/Warrior Forge is the crucible of the Army ROTC Program. As such, Cadet Command must provide the best professional training and evaluation possible for all cadets. The primary focus at LDAC is to evaluate each cadet's officer potential in a collective environment. The secondary purpose of LDAC is to validate specific skills taught on campus and to impart selective individual and collective common skills. LDAC represents the only opportunity for this command to assemble cadets from disparate schools into an environment with common operational conditions.

Senior Year - Advanced Course

MS 401: Developing Adaptive Leaders 3R-3L-4C F Pre: MS 303

MS 401 develops cadet proficiency in planning, executing, and assessing complex operations, functioning as a member of a staff, and providing performance feedback to subordinates. Cadets assess risk, make ethical decisions, and lead fellow ROTC cadets. Lessons on military justice and personnel processes prepare cadets to make the transition to Army officers. Cadets analyze, evaluate, and instruct cadets at lower levels. Both their classroom and battalion leadership experiences are designed to prepare cadets for their first unit of assignment.

They identify responsibilities of key staff, coordinate staff roles, and use situational opportunities to teach, train, and develop subordinates.

MS 402: Leadership in a Complex World 3R-3L-4C W Pre: MS 401

MS 402 explores the dynamics of leading in the complex situations of current military operations in the COE. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. They also explore aspects of interacting with nongovernmental organizations, civilians on the battlefield, and host nation support. The course places significant emphasis on preparing cadets for their first unit of assignment. It uses case studies, scenarios, and What Now, Lieutenant? exercises to prepare cadets to face the complex ethical and practical demands of leading as commissioned officers in the United States Army.

MS 403: Leadership in a Complex World II 3R-3L-4C S Pre: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Pre: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

R

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https://www.rose-hulman.edu/course-catalog/course-catalog-2012-2013/course-descriptions/multi-disciplinary-studies.aspx[1/20/2017 12:52:09 PM]

measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems.

OE 395 Optical Instrumentation 3R-3L-4C Arranged Pre: OE 280 and PH 292

Radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; signal conditioning and noise; CCD arrays; optical instruments; color; selected experiments on the application of optical instruments.

OE415 Optical Engineering Design I 2R-6L-4C S Pre: OE 295 Coreq: RH330 or consent of the instructor

Principles of design. Codes of ethics appropriate to optical engineers. Case studies related to optical engineering professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415. OE416 Optical Engineering Design II 2R-6L-4C F Pre: OE 415

Design project using formal design process; system-level design. Students work in teams to complete the first phase of the design. Teams translate customer needs to design specifications. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE417 Optical Engineering Design III 2R-6L-4C W Pre: OE416

Continuation of OE416 design project. Delivery of a functional prototype product. Complete product development documentation including a technical report, design documents, product design specification, drawings, acceptance test document, project plan. Oral presentation. Cross-listed with EP 417.

OE 435 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 435.

OE 450 Laser Systems and Applications 3R-3L-4C S Pre: PH 292 and MA 212 or JR standing or consent of instructor

Laser safety; Gaussian beam propagation; beam quality; optical resonators; longitudinal and transverse modes; stability, stimulated emission; population inversion; rate equations; gain and threshold; Q-switching and mode-locking; types of laser systems; laser applications.

OE 470 Special Topics in Optical Engineering 2-4 Credits Pre: Consent of instructor

Lectures on special topics in optics.

OE 480 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 Coreq: OE 360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Glass selection and introduction to computer-aided design. Classical lens design and design of imaging /non-imaging systems. Cross-listed with OE 580.

OE 485 Electro-Optics and Applications 3R-3L-4C W Pre: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Cross-listed with OE 595.

OE 490 Directed Research Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3R-3L-4C F Pre: OE393, ECE310 or graduate standing or consent of the instructor

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Soliton propagation. Relevant laboratories

OE 495 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-

Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); Review of interference and coherence; fringe visibility; third order aberrations; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Cross-listed with 595.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Pre: OE 295, PH 292, PH 316 or SR/GR standing or consent of instructor

Classical optics; exact ray tracing; aberrations, interference, polarization, spatial and temporal coherence; lasers and Gaussian beam propagation; diffraction; optical sources and detectors; selected applications of optics.

OE 535 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 535.

OE 570 Special Topics in Optics 2 or 4C F,W,S Pre: OE 295, PH 292, and PH 316

Lectures on special topics in optics such as: optical materials, optics of thin films and infrared optics.

OE 580 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 Coreq: OE360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Glass selection and introduction to computer-aided design. Classical lens design and design of imaging/ non-imaging systems. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 480.

OE 585 Electro-Optics and Applications 3R-3L-4C W Pre: PH 292 and

PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 485.

OE 592 Fourier Optics and Applications 3R-3L-4C F Pre: SR/GR standing or consent of instructor

Two-dimensional linear systems; diffraction theory (Fresnel & Fraunhofer); imaging properties of lenses; frequency analysis of optical imaging systems; spatial filtering; optical information processing; Vander-Lugt filters; wavefront reconstruction; holography; optical computing.

OE 593 Fundamentals of Optical Fiber Communications 3R-3L-4CS

Pre: OE393 or graduate standing or consent of the instructor

Evolution of fiber optics links and networks: information rate, evaluation of fiber optic systems, optical fiber transmission link. Digital transmission systems: point-to-point links, line coding, error correction. Analog systems: links, dynamic range, noise figure, bandwidth, carrier-to-noise, multi-channel transmission, cross talk. WDM concepts: operational principles, passive components, system considerations. Optical networks: network topologies, performance of linear bus, performance of star architecture, SONET, WDM networks, wavelength-routed networks, optical CDMA, ultra high capacity WDM networks, bit-interleaved optical TDM, time-slotted optical TDM.

Students enrolled in OE593 must do project work on a topic selected by the instructor.

OE 594 Guided-Wave Optics 3R-3L-4C S Pre: OE 485 or SR/GR standing or consent of instructor


Theory of optical waveguides; waveguide modes; fabrication techniques; input and output coupling techniques; waveguide losses; waveguide gratings; electro-optic modulators; integrated optical detectors; applications of integrated optics.

OE 595 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); Review of interference and coherence; fringe visibility; third order aberrations; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 495.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.

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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, McInerney, Moloney, Siahmakoun, Sirohi, Syed, and Wagner.

Note: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

PHPP Calculus III, PH111, PH112– Phast Physics 12R-3L-13C Pre: One year of college level calculus (BC Calculus or equivalent), one year of high school physics, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Phast Physics Selection Committee.

A 5-week intensive immersion into calculus and physics which covers the equivalent of Calculus III, and Physics I, II. Taught only to incoming freshman who have demonstrated outstanding ability in both calculus and physics. Review of single variable calculus, both differential calculus and integral calculus, as needed. Covers from MA113: vectors and parametric equations in three dimensions, functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems with applications of vectors, parametric equations, partial derivatives and multiple integrals. Covers from PH111, PH112: kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, conservation of energy and momentum, torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, with relevant laboratory experiments.

PH 111 Physics I 3.5R-1.5L-4C F, W Coreq: MA 111

Kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, strong and weak nuclear forces, conservation of energy and momentum, relevant laboratory experiments.

PH 112 Physics II 3.5R-1.5L-4C W, S Pre: PH 111 and MA 111; Co: MA 112

Torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, relevant laboratory experiments.

PH 113 Physics III 3.5R-1.5L-4C S, F Pre: PH 112 and MA 112; Coreq: MA 113

Sources of magnetic fields, Faraday's law, inductance electromagnetic waves, reflection and polarization, geometric and physical optics, introduction to relativity, relevant laboratory experiments.

PH 200 Career Preparation 1R-0L-1C W,S

This course is for physics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, MA200 and SV200.

PH 215 Introduction to CHAOS 2R-0L-2C W

What constitutes chaotic behavior, detection of chaos in real systems using phase space plots, Poincare sections, bifurcation plots, power spectra, Lyapunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Pre: MA 111, and PH 111 or EM 120

Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Pre: PH 111 or Coreq: EM 202; and Coreq: MA 112

Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Pre: MA 111, and PH 111 or EM 120

Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Pre: MA 111, and PH 111 or EM 120

Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Pre: PH 113 and Coreq: MA 211

Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Pre: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Pre: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Pre: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Pre: PH 113

The wave equation; electromagnetic waves; phase and group velocities; complex refractive index; dispersion, interference; interferometers and applications, optical interferometry; coherence; polarized light; Jones vectors/matrices; production of polarized light; birefringence, Fraunhofer diffraction; diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Pre: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Pre: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S, Arranged Pre: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W, Arranged Pre: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Pre: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Pre: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Pre: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Pre: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication,

transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Pre: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 330 Material Failure 3R-3L-4C W Pre: PH 113

Physical principles of instrumentation used for material failure analysis, including light microscopy, electron microscopy, and spectroscopy. Laboratory includes experiments and case studies using these instruments.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Pre: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schrodinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schrodinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Pre: PH 113, and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Cross-listed with PH 505.

PH 407 Solid State Physics 4R-0L-4C S (even years) Pre: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Pre: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Pre: MA 212, and JR/SR or Graduate standing

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory.

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Pre: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Pre: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Pre: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Pre: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Pre: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Pre: Consent of instructor

Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Robotics

ROBO 410 Robotics Capstone Design I 1R-6L-4C F
Pre for EE or CPE: ECE 362, and a co-requisite ME 430
Pre for ME: ME senior class standing, and co-requisites of ME 430 and ME 470
Pre for CS or SE: RH 330 and CSSE 374, and a co-requisite ME 430

ROBO 420 Robotics Capstone Design II 1R-6L-4C W
Pre: ROBO 410

ROBO 430 Robotics Capstone Design III 1R-6L-4C S
Pre: ROBO 420

Description: Interdisciplinary group robotics engineering project. This requires the carrying out, from inception to completion, of a robotics-related system development for an approved client. The focus for students from each major is on design appropriate to that major related to robotics. Teamwork activities are expected to involve coordination of multidisciplinary aspects of the project, team planning, leading, and reviewing of project progress versus risks. Engineering practices related to design include requirements and constraint analysis and management, design creation and documentation, prototyping, system construction and testing, following of engineering standards, and management of intellectual property. Technical completion and delivery to the client is expected.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Sophomore Engineering

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 211 Differential Equations (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 212 Matrix Algebra & Systems of Differential Equations (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals
This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,
- develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,
- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,

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- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
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- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
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- Humanities and Social Sciences
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- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Pre: MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid & Thermal Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better

Conservation and accounting equations applied to fluid and thermal systems. Fluid and thermodynamic properties of pure substances. Open and closed systems hydrostatics. Dimensional analysis. Mechanical energy balance and pipe flow. Lift and drag.

ES 203 Electrical Systems; 3R-3L-4C; F,W,S; Pre: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better Co: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Pre: ES 202, ES 203 with a grade of C or better, OR ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Applied Biology

The twenty-first century will see unparalleled advances in the biological sciences. Disciplines such as applied biology and biomedical engineering are burgeoning and will greatly impact the way we live in the future. The areas of functional genomics and proteomics will drive discoveries in molecular medicine, gene therapy and tissue engineering. Drug discovery will be facilitated by the elucidation of new target molecules and many pharmaceutical compounds will be produced using biological processes. Environmental management, remediation and restoration will also benefit from advances in applied biology. Biologists will be at the forefront of these advances and will drive the medical, agricultural, environmental and industrial applications of biological sciences.

The applied biology program will produce biologists with the chemistry, mathematics, and physics background needed to solve biotechnological problems in the coming decades. Those students wishing to strengthen their engineering skills can earn the area minor in biomedical engineering. Other students may choose to pursue a second major in Biochemistry and Molecular Biology. The program will prepare graduates for professional careers in government and industrial research laboratories, and in the biotechnology and health-related industries.

Those wishing to continue their studies in graduate or health professions programs will be exceptionally well qualified to do so.

APPLIED BIOLOGY PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
AB 110	Cell Structure and Function	4	AB 210	Mendelian &	4
CHEM 111	General Chemistry	4		Molecular Genetics	
MA 111	Calculus I	5	CHEM 251	Organic Chemistry I	3
CLSK 100	College & Life Skills	1	CHEM 251L	Organic Chemistry I	1
	Total	14		Laboratory	
Winter Term		Credit	PH 111	Physics I	4
AB 120	Comparative Anatomy & Physiology	4	MA 212	Matrix Algebra and Systems of	4
CHEM 113	General Chemistry II	4		Differential Equations	
MA 112	Calculus II	5		Total	16
BE 100	Problem Solving in the Biological Sciences and Engineering	4	Winter Term		Credit
	Total	17	AB 220	Prokaryotic Cell & Molecular Biology	4
Spring Term		Credit	CHEM 252	Organic Chemistry II	4
AB 130	Evolution and Diversity	4	PH 112	Physics II	4
CHEM 115	General Chemistry III	4	RH 330	Technical and Professional Communication	4
MA 113	Calculus III	5		Total	16
RH 131	Rhetoric & Composition	4	Spring Term		Credit
	Total	17			

- Applied Biology
- Biochemistry
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- Engineering Physics
- Mathematics
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Additional Programs of Study

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- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

AB 230	Eukaryotic Cell & Molecular Biology	4
CHEM 253	Organic Chemistry III	4
PH 113	Physics III	4
MA 223	Engineering Statistics	4
	Total	16

Junior			Senior Year		
Year			Fall Term		Credit
Fall Term		Credit	AB 499	Thesis Research	4
AB 320	Ecology	4		Science/Technical Elective	4
AB	Elective	4	HSS	Elective	4
RH 330	Technical and Professional	4		Free Elective	4
Or HSS	Communication or Elective			Total	16
AB 301	Jr. Colloq	1	Winter Term		Credit
	Total	17	AB 401	Sr. Colloq	2
Winter Term		Credit		Science/Technical Elective	4
AB 330	Evolutionary Biology	4	AB 499	Thesis Research	4
CHEM 330	Biochemistry	4	HSS	Elective	4
				Total	14
AB	Elective	4	Spring Term		Credit
HSS or	Elective or Technical and	4	AB	Elective	4
RH 330	Professional Communication			Science/Technical Elective	4
AB 302	Jr. Colloq	1	HSS	Elective	4
	Total	17		Total	16
Spring Term		Credit	Total credits required:		188
AB 310	Plant Structure & Function	4			
AB 497	Thesis Research II	4			
SV 304	Bioethics	4			
HSS	Elective	4			
	Total	16			

An AB science/technical elective is any Rose-Hulman course that has a prefix of AB, BE, CHEM, CHE, CE, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required AB courses	52 credits
AB electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	12 credits
Required MA, CHEM, PH	63 credits
Required CLSK	1 credit
Sci/Tech electives	12 credits
Required BE course	4 credits
Total	188 credits

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility. Two faculty are

directly involved with this program: Dr. Mark Brandt, assistant professor of chemistry, is the program coordinator and is a biochemist, and Dr. Richard Anthony, associate professor of applied biology, is a molecular biologist. Many other faculty in both the chemistry and applied biology departments assist with this curriculum.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required Courses

			Elective Courses	
Course	Description	Hours	Choose 12 credits* from the following courses:	
CHEM 111, 113, 115	General Chemistry	12		
CHEM 251, 252, 253	Organic Chemistry	9		
CHEM 330, 430, 433	Biochemistry	9	AB 330	Evolutionary Biology
CHEM 361, 362			AB 421	Applied Microbiology
or			AB 431	Genomics and Proteomics
CHEM 360			AB 441	Virology
and			AB 451	Cancer Biology
CHE 303, 304	Physical Chemistry	8	AB 492	Directed Study in Applied Biology
AB 110, 120, 130	Biology	12	CHEM 225	Analytical Chemistry
AB 210	Genetics	4	CHEM 291	Introduction to Research
AB 220, 230	Molecular Biology	8	CHEM 331	Biochemistry II
AB 411	Genetic Engineering	4	CHEM 431	Biochemical Instrumentation
Total		69	CHEM 451	Organic Structure Determination
			CHEM 290	
			or	
			CHEM 490	Chemical Research
			PH 302	Biophysics

Total Credits for Second Major 81

*Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the AB electives listed, and 4 credits chosen from any AB or BE course.

Students with a major in applied biology must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above AB course (total: 29 hours required beyond Applied Biology major).

Applied Biology Area Minor

The Area Minor in Applied Biology is designed to allow students to enrich studies in their major area. Students wishing to apply another science, mathematics, or engineering discipline to investigate or solve problems in biological systems are encouraged to pursue the Area Minor in Applied Biology. With proper course selection, the Area Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Area Minor in Applied Biology has the following requirements.

1. All students must complete AB110 (Cell Structure and Function) or AB130 (Evolution and Diversity) and at least four more courses in applied biology (AB) or allied areas, above those courses already specifically required to fulfill the student's major.
 - a. At least three of the four electives must be AB courses.
 - b. At least three of the electives must be 200-level or above.Additional courses not listed in the approved allied areas can be considered on a case-by-case basis. See ABBE Department Head.
2. Students electing to pursue the Area Minor in Applied Biology must follow a plan of study that is approved by the Area Minor Advisor. Current advisor information and a form for the planning and approval of an


area minor can be obtained from the ABBE Department secretary.

3. Allied area courses could include:
- BE 310 Analysis of Physiological Systems I
 - BE 320 Analysis of Physiological Systems II
 - BE/MA 482 Bioengineering Statistics
 - BE 570 Introduction to Tissue Engineering
 - CE 460 Introduction to Environmental Engineering
 - CHE 545 Introduction to Biochemical Engineering
 - CHEM 264 Environmental Chemistry
 - CHEM 330 Survey of Biochemistry
 - CHEM 430 Advanced Biochemistry
 - PH 302 Biophysics
 - SL 386 Human Evolution
 - VA 373 Gender Issues

Biochemistry & Molecular Biology Area Minor

Completion of AB110, CHEM111, CHEM113 and CHEM115. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

- AB 210 Mendelian and Molecular Genetics
- AB 220 Prokaryotic Cell and Molecular Biology
- or
- AB 230 Eukaryotic Cell and Molecular Biology
- AB 411 Genetic Engineering
- or
- AB 431 Genomics and Proteomics
- CHEM Introduction to Organic Chemistry and
- 230 Biochemistry
- or
- CHEM Organic Chemistry I
- 251
- and
- CHEM Organic Chemistry II
- 252
- CHEM Biochemistry
- 330
- CHEM Advanced Biochemistry
- 430
- with
- CHEM Biochemistry Laboratory
- 433



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Biochemistry Plan of Study

Freshman Year			Sophomore		
Fall Term			Year		
CHEM 111*	General Chemistry I	4	Fall Term		Credit
MA 111	Calculus I	5	CHEM 251	Organic Chemistry I	4
AB 110	Cell Structure & Function	4	PH 113	Physics III	4
CLSK 100	College & Life Skills	1	MA 212	Matrix Algebra and	4
RH 131	Rhetoric and Composition	4		Systems	
	or			of Differential Equations	
HSS	Elective		AB 210	Mendelian &	4
	Total	18		Molecular Genetics	
				Total	16
Winter Term			Year		
CHEM 113*	General Chemistry II	4	Winter Term		Credit
MA 112	Calculus II	5	CHEM 200	Career Preparation	1
PH 111	Physics I	4		(take in winter or spring)	
RH 131	Rhetoric and Composition	4	CHEM 252	Organic Chemistry II	4
	or		CHEM 291	Intro to Undergraduate	4
HSS	Elective			Research	
	Total	17	MA 381	Introduction to Probability	4
				with Applications to	
Spring Term				Statistics	
CHEM 115	General Chemistry III	4	AB 220	Prokaryotic Cell &	4
MA 113	Calculus III	5		Molecular Biology	
PH 112	Physics II	4		Total	16 or
HSS	Elective	4			17
	Total	17			
			Spring Term		
			CHEM 200	Career Preparation	1
				(take in winter or spring)	

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
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Additional Programs of Study

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			CHEM 253	Organic Chemistry III	4
Junior Year			CHEM 225	Analytical Chemistry	4
Fall Term		Credit	AB 230	Eukaryotic Cell &	4
CHEM 326	Bioanalytical Chemistry	4		Mol. Biology	
CHEM 330	Biochemistry I	4	HSS	Elective	4
CHEM 361	**Physical Chemistry I	4		Total	16 or
HSS	Elective	4			17
Total		16			
Winter Term					
CHEM 327	Advanced Analytical	4			
CHEM 362	**Physical Chemistry II	4			
CHEM 331	Biochemistry II	4	Senior Year		
CHEM 400	Chemical Communication I	1	Fall Term		Credit
HSS	Elective	4	CHEM 441	Inorganic Chemistry I	4
Total		17	CHEM 401	Chemical Communication II	1
Spring Term			CHEM 490	Chemistry Research	1
CHEM 363	Quantum Chemistry &	4		##Advanced Chemistry or	
	Molecular Spectroscopy			Biochemistry Elective	4
CHEM 430	Advanced Biochemistry	4		Advanced Biology Elective	4
CHEM 433	Biochemistry Lab	1		Free Elective	4
HSS	Elective	4		Total	18
CHEM 490#	Research	1	Winter Term		Credit
Total		14	CHEM 402	Chemical Communication III	1
			CHEM 490	Chemistry Research	1
			HSS	Elective	4
				##Advanced Biology,	4
				Chemistry, Biochem	
				Free Elective	
				Total	14
			Spring Term		Credit
			CHEM 403	Chemical Communication IV	1
			CHEM 490	Chemistry Research	1
				HSS Elective	4
				Free Elective	4
				Free Elective	4
				Total	14
				Total credits required:	194

Notes: Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM111 General Chemistry I is an automatic substitution for the former CHEM105 Engineering Chemistry I.

CHEM113 General Chemistry II is an automatic substitution for the former CHEM107 Engineering Chemistry II.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits	Summary of minimum graduation requirements:			
General Chemistry	111, 113, 115	12				
Organic Chemistry	251, 252, 253	12				
Analytical Chemistry	225, 326, 327	12	Course or areas	Required	Elective	Total
Physical Chemistry	361, 362, 363	12	Chemistry	78	8	86
Inorganic Chemistry	441	4	Physics	12	0	12
Biochemistry	330, 331, 430, 433	13	Mathematics	23	0	23
Research	291, 490	8	Biology	20	0	20
			Humanities and Social	4	32	36

Chemical Communication	400, 401, 402, 403	4				
Career Preparation	200	1	Sciences			
Electives		8	Electives	0	16	16
Total		86	College and Life Skills	1	0	1
			Total	136	56	194


Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
*CHEM111	General Chemistry I	4
*CHEM113	General Chemistry II	4
*CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		32

*CHEM 105 and CHEM 107 can be substituted for CHEM111You may replace CHEM111, CHEM 113, and CHEM 115.

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors
Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225 or CHEM253	Analytical Chemistry Organic Chemistry III	4
CHEM330 or CHEM361	Biochemistry I Physical Chemistry I	4
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

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- Pre-Professional Programs

- be able to design and conduct experiments, making measurements from both living and non-living systems.
- be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- be able to function in multidisciplinary teams in different roles.
- be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- have the skills required for self-learning.
- be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
AB 110	Cell Structure and Function	4	ES 201	Conservation & Accounting Principles	4
PH 111	Physics I	4	CHEM 111	General Chemistry I	4
MA 111	Calculus I	5	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	ES 203	Electrical Systems	4
EM 104	Graphical Communication	2		Total	16
	Total	16			
Winter Term		Credit	Winter Term		Credit
AB 120	Comparative Anatomy & Physiology	4	ES 202	Fluid and Thermal Systems	3
PH 112	Physics II	4	ES 204	Mechanical Systems	3
MA 112	Calculus II	5	MA 212	Matrix Algebra and Systems of Differential Equations	4
BE 100	Problem Solving in the Biological Sciences and Engineering	4	CHEM 113	General Chemistry II	4
	Total	17	HSS	Elective	4
			Total		18
Spring Term		Credit	Spring Term		Credit
PH 113	Physics III	4	BE 201	Biomedical Measurements	4
RH 131	Rhetoric & Composition	4	AB 130	Evolution and Diversity	4
MA 113	Calculus III	5	ES 205	Analysis & Design of Engineering Systems	4
EM 121	Statics and Mechanics of Materials I	4	MA 223	Engineering Statistics	4
	Total	17	Total		16
Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
HSS	Elective	4	BE 410	Biomedical Engineering Design I	4
AB 205	Cellular Physiology	4	HSS	Elective	4
RH 330	Technical and Professional Communication	4		Free Elective	4
HSS					

	or		BE	Area Elective	4
	Elective			Total	16
EM 204	Statics and	4	Winter Term		Credit
	Mechanics of Materials II		BE 420	Biomedical Engineering	4
	Total	16		Design II	
Winter Term		Credit	HSS	Elective	4
BE 310	Physiological Systems I	4		Free Elective	4
BE 331	Biomechanics	3	BE	Area Elective	4
BE 351	Biomedical Engineering Lab	2		Total	16
BE 361	Biomaterials	3	Spring Term		Credit
HSS	Elective	4	BE 430	Biomedical Engineering	2
	or			Design III	
RH 330	Technical and		HSS	Elective	4
	Professional			Free Elective	4
	Communication		BE	Area Elective	4
	Total	16		Total	14
Spring Term		Credit	Total credits required:		192
SV 304	Bioethics	4			
BE 320	Physiological Systems II	4			
BE 390	Principles of Biomedical	2			
	Engineering Design				
BE	Area	4			
	Total	14			

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the ABBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 417	Advanced Materials
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanincs
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both
**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols
BE 516	Introduction to MEMS
BE 435/535	Biomedical Optics
BE 555	Electrophysiology

ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course Title

ME 317**Design for Manufacturing
and

BE 317** Design for Biomedical Manufacturing

BE 525 Biomedical Fluid Mechanics

BE 531 Biomechanics II

BE 534 Soft Tissue Mechanics

BE 539 Multiscale Biomechanics

BE 545 Orthopaedic Biomechanics

BE 550 Research Methods in Biomechanics

EM 403 Advanced Mechanics of Materials

ME 422 Finite Elements for Engineering Applications

ME 520 Computer-Aided Design and Manufacturing

ME 522 Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Area Minor

The biomedical engineering area minor is intended to provide a strong biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and the health care related fields.

In order to complete the requirements in the biomedical engineering area minor, a student must complete AB110 "Cell Structure and Function" and 16 credits from list shown below. At least three of the courses must have a BE prefix.

Biomedical Engineering Minor Electives

PH 302	4	Biophysics
AB 411	4>	Genetic Engineering
BE 310	4	Analysis of Physiological Systems I
BE 320	4	Analysis of Physiological Systems II
BE 331		Biomechanics
BE 340	4	Biomedical Instrumentation
BE 350	4	Biocontrol Systems
BE 351	2	Biomedical Engineering Lab *
BE 352	1	Biomechanics Lab *
BE 353	1	Biomaterials Lab *
BE 361	3	Biomaterials
BE 435/5354		Biomedical Optics
BE 482	4	Bioengineering Statistics
BE 510	4	Biomedical Signal and Image Processing
BE 525	4	Biomedical Fluid Mechanics
BE 531	4	Biomechanics II

BE 534	4	Soft Tissue Mechanics
BE 539	4	Multiscale Biomechanics
BE 541	4	Medical Imaging
BE 543	4	Neuroprosthetics
BE 545	4	Orthopaedic Biomechanics
BE 550	4	Research Methods in Biomechanics
BE 555	4	Electrophysiology
BE 560	4	Tissue-Biomaterial Interactions
BE 570	4	Introduction to Tissue Engineering

*Students getting credit for BE351 cannot get credit for BE352 or BE353.

In addition to courses on the above list, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

Basic Engineering Courses

- EM 121 Statics and Mechanics of Materials I
- EM 204 Statics and Mechanics of Materials II
- EM 301 Fluid Mechanics
- ECE 130Introduction to Logic Design
- ECE 200Circuits & Systems
- ES 201 Conservation & Accounting Principles
- ES 202 Fluid & Thermal Systems
- ES 203 Electrical Systems
- ES 204 Mechanical Systems
- CHE 201Conservation Principles and Balances
- CHE 202Basic Chemical Process Calculations
- CHE 301Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the Head of the Department of Applied Biology and Biomedical Engineering.



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Current Students	Alumni and Friends	Trustees
Incoming Freshman	Community Members	Parents

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INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives
Program Educational Objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve in three to five years.

- Apply a strong academic foundation to make early career contributions to the profession.
- Work in teams to tackle diverse, open-ended problems and to effectively communicate their findings.
- Apply skills for a long-term, productive career in an ever changing global environment.

Student Outcomes
Student Outcomes are statements that describe what students are expected to have by the time of graduation.

1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to identify, formulate, and solve engineering problems
3. An ability to design and conduct experiments and analyze and interpret data
4. An ability to design a system or process to meet desired needs within realistic constraints
5. An ability to function on multidisciplinary teams
6. An ability to communicate effectively in presentations and reports
7. An ability to use the techniques, skills, and modern engineering tools (particularly computer-based tools) necessary for engineering practice
8. An understanding of the professional and ethical responsibilities of a chemical engineer
9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
10. The preparation to engage in life-long learning
11. A knowledge of contemporary issues

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)
Biochemistry & Molecular Biology (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degrees of Master of Science in chemical engineering or Master of Chemical Engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required for the Master of Science degree, but not for the Master of Chemical Engineering degree. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)			Freshman Year (A2 Schedule)		
Fall Term		Credit	Fall Term		Credit
CHEM 111	General Chemistry I*	4	CHEM 111	General Chemistry I*	4
CLSK 100	College & Life Skills	1	CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2	EM 104	Graphical Communications	2
RH 131	Rhetoric & Composition	4	RH 131	Rhetoric & Composition	4
MA 111	Calculus I	5	MA 111	Calculus I	5
Total		16	Total		16
Winter Term		Credit	Winter Term		Credit
CHEM 113	General Chemistry II*	4	CHEM 113	General Chemistry II*	4
PH 111	Physics I	4	PH 111	Physics I	4
HSS	Elective	4	HSS	Elective	4
MA 112	Calculus II	5	MA 112	Calculus II	5
Total		17	Total		17
Spring Term		Credit	Spring Term		Credit
CHE 110	Programming & Computation for Chemical Engineers	2	CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4	CHEM 115	General Chemistry III	4
EM 103	Introduction to Design	2	EM 103	Introduction to Design	2
MA 113	Calculus III	5	MA 113	Calculus III	5
PH 112	Physics II	4	PH 112	Physics II	4
Total		17	Total		17
Sophomore Year			Sophomore Year		
(A1 Schedule)			(A2 Schedule)		
Fall Term		Credit	Fall Term		Credit
CHE 200	Career Preparation I	0	CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4	CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	4	CHEM 251	Organic Chemistry I	4
MA 211	Differential Equations	4	MA 211	Differential Equations	4
EM 101	Statics I	2	EM 101	Statics I	2
Total		14	Total		14
Winter Term		Credit	Winter Term		Credit
CHE 202	Basic Chemical Process Calculations	4	CHE 202	Basic Chemical Process Calculations	4

CHEM 252	Organic Chemistry II	4	CHEM 252	Organic Chemistry II	4
MA 212	Matrix Algebra and Systems	4	MA 212	Matrix Algebra and Systems	4
	of Differential Equations			of Differential Equations	
HSS	Elective	4	HSS	Elective	4
	Total	16		Total	16
Spring Term		Credit	Spring Term		Credit
CHE 301	Fluid Mechanics	4	MA 223	Engineering Statistics I	4
CHE 303	Chemical Engineering	4	CHEM 225	Analytical Chemistry I	4
	Thermodynamics		HSS	Elective	4
	Elective (Approved)	4	CHE 315	Materials Science	4
HSS	Elective	4		Total	16
	Total	16			

Junior Year		
(A1 Schedule)		
Fall Term		Credit
CHE 300	Career Preparation II	0
CHE 304	Multi-Component	4
	Thermodynamics	
CHE 314	Heat Transfer	4
CHE 315	Materials Science	4
CHEM 225	Analytical Chemistry I	4
	Total	16
Winter Term		Credit
CHE 325	Mass Transfer	4
CHEM 360	Intro Physical Chemistry	4
MA 223	Engineering Statistics I	4
RH 330	Technical and	4
	Professional Communication	
	Total	16
Spring Term		Credit
CHE 404	Kinetics & Reactor Design	4
CHE 411	Chemical Engineering Lab I	3
ECE 206	Elements of	4
	Electrical Engineering	
HSS	Elective	4
	Total	15

Junior Year			Senior Year		
(A2 Schedule)			(A1 Schedule)		
Fall Term		Credit	Fall Term		Credit
CHE 300	Career Preparation II	0	CHE 409	Professional Practice	1
CHE 301	Fluid Mechanics	4	CHE 412	Chemical Engineering Lab II	4
CHE 303	Chemical Engineering	4	CHE 416	Design I	4
	Thermodynamics			Free Elective(Free)	4
	Elective (Approved)	4		Free Elective(CHE)	4
RH 330	Technical and	4		Total	17
	Professional Communication		Winter Term		Credit
	Total	16	CHE 413	Chemical Eng. Lab III	4
Winter Term		Credit	CHE 417	Design II	4
CHE 304	Multi-Component	4	CHE 440	Process Control	4
	Thermodynamics		HSS	Elective	4
CHE 314	Heat Transfer	4		Total	16
ECE 206	Elements of	4	Spring Term		Credit
	Electrical Engineering		CHE 418	Design III	2
HSS	Elective	4	HSS	Elective	4
	Total	16	HSS	Elective	4
Spring Term		Credit		Elective(Approved)	4

CHE 325	Mass Transfer	4	Elective(CHE)	4
CHE 411	Chemical Engineering Lab I	3	Total	18
CHEM 360	Intro Physical Chemistry	4	Total credits required:	194
HSS	Elective	4		
	Total	15		

Senior Year			
(A2 Schedule)			
Fall Term			Credit
CHE 404	Kinetics & Reactor Design		4
CHE 409	Professional Practice		1
CHE 412	Chemical Engineering Lab II		4
CHE 416	Design I		4
	Free Elective(Free)		4
	Total		17
Winter Term			Credit
CHE 413	Chemical Eng. Lab III		4
CHE 417	Design II		4
CHE 440	Process Control		4
HSS	Elective		4
	Total		16
Spring Term			Credit
CHE 418	Design III		2
HSS	Elective		4
	Elective(CHE)		4
	Elective(CHE)		4
	Elective(Approved)		4
	Total		18
	Total credits required:		194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in a particular subject area.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become

essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although it is recommended that a minimum of eight credit hours be focused in one subject area, students are encouraged to focus most or all of the 20 credit hours of electives in a particular subject area. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering, toward a certificate in semiconductor materials and devices, or toward an area of concentration (see below).

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward an approved elective.

Area Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 325 Mass Transfer
- CHE 314 Heat Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Area Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- AB110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology
- or
- AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering
- AB421 - Applied Microbiology
- AB431 - Genomics and Proteomics
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary

AREA OF CONCENTRATION

Although it is not a requirement, students may pursue a concentration in one or more of the following areas. Students who complete the requirements of a concentration may receive, upon request, a letter from the Department Head that attests to the fact that the requirements have been completed. Students may not count courses towards a concentration that also count towards another concentration or towards a minor, certificate, double major, or second degree. With proper planning, a student should be able to complete the requirements for an area of concentration without overload.

Advanced Chemical Engineering Analysis

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 450 Air Pollution
- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma
- MA 444 Deterministic Models in Operations Research

Engineering Management List

- EMGT524 Production/Operations Management
- EMGT527 Project Management
- EMGT534 Management Science
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems



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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include applied biology, chemical engineering and mathematics.

CHEMISTRY PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term		Credit	Year		Credit
CHEM 111*	General Chemistry	4	Fall Term		
MA 111	Calculus I	5	CHEM 251	Organic Chemistry I	4
AB 110**	Cell Structure and	4	PH 113	Physics III	4
	Function		MA 212	Matrix Algebra and	4
CLSK 100	College & Life Skills	1		Systems	
RH 131	Rhetoric and Composition	4		of Differential Equations	
	or			Free Elective	4
HSS	Elective			Total	16
	Total	18	Winter Term		Credit
Winter Term		Credit			
CHEM 113*	General Chemistry II	4	CHEM 200	Career Preparation	1
MA 112	Calculus II	5		(take in winter or spring)	
PH 111	Physics I	4	CHEM 252	Organic Chemistry II	4
RH 131	Rhetoric and Composition	4	CHEM 291	Intro to Undergraduate	4
	or			Research	
HSS	Elective		MA 381	Introduction to Probability	4
	Total	17		with Applications to	
				Statistics	
Spring Term		Credit			
CHEM 115	General Chemistry III	4		Free Elective	4
MA 113	Calculus III	5		Total	16 or
HSS	Elective	4			17
			Spring Term		Credit

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

PH 112	Physics II	4	CHEM 200	Career Preparation	1
	Total	17		(take in winter or spring)	
			CHEM 253	Organic Chemistry III	4
			CHEM 225	Analytical Chemistry I	4
			HSS	Elective	4
				Free Elective	4
Junior Year			Total		16 or
Fall Term		Credit			17
CHEM 326	Bioanalytical Chemistry	4			
CHEM 361	***Physical Chemistry I	4			
CHEM 330	Biochemistry I	4			
HSS	Elective	4			
	Total	16	Senior Year		
Winter Term		Credit	Fall Term		Credit
CHEM 327	Advanced Analytical	4	CHEM 441	Inorganic Chemistry I	4
CHEM 362	***Physical Chemistry II	4	CHEM 401	Chemical Communications II	1
CHEM 400	Chemical Communications I	1	CHEM 490	Research	1
HSS	Elective	4		Chemistry Elective	4
	Free Elective	4		Free Elective	4
	Total	17	Total		14
Spring Term		Credit	Winter Term		Credit
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4	CHEM 442	Inorganic Chemistry II	4
CHEM 451	Organic Structure Determination	4	CHEM 402	Chemical Communications III	1
HSS	Elective	4	CHEM 490	Research	1
	Free Elective	4	HSS	Elective	4
CHEM 490#	Research	1		Chemistry Elective	4
	Total	17		(400-level)###	
			Total		14
			Spring Term		Credit
			CHEM 403	Chemical Communications IV	1
			CHEM 490	Research	1
			HSS	Elective	4
				Free Elective	4
				Free Elective	4
			Total		14
			Total credits required:		193

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

CHEM111 General Chemistry I is an automatic substitution for the former CHEM105 Engineering Chemistry I.

CHEM113 General Chemistry II is an automatic substitution for the former CHEM107 Engineering Chemistry II.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113.

AB120 or AB130 may be substituted for AB110 *CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits	Summary of minimum graduation requirements:		
General Chemistry	111, 113, 115	12			
Organic Chemistry	251, 252, 253	12			
Analytical Chemistry	225, 326, 327	12	Course or areas	Required	Elective Total
Physical Chemistry	361, 362, 363	12	Chemistry	77	8 85
Inorganic Chemistry	441, 442	4	Physics	12	0 12
Biochemistry	330	4	Mathematics	23	0 23
Organic Structure	451	4	Biology	4	0 4
Determination			Humanities and Social	4	32 36

Chemical Communication	400, 401, 402, 403	4	Sciences			
			Electives	0	32	32
Research	291, 490	8	College and Life Skills	1	0	1
Career Preparation	200	1	Total	121	76	193
Electives		8				
Total		85				

Area Minor in Chemistry
Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully

completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in applied biology or chemical engineering are different from those majoring in other disciplines.

Area Minor in Chemistry for Most Students

Course Number	Course Title	Credits	*Approved list of chemistry electives includeCHEM253, CHEM290 (up to two credit hours), CHEM291, or any 300 or 400 level chemistry courses.			
CHEM113	General Chemistry II	4				
CHEM115	General Chemistry III	4				
CHEM225	Analytical Chemistry	4				
CHEM251	Organic Chemistry I	4				
CHE252	Organic Chemistry II	4				
	*Approved List of Chemistry Electives	4	Course Number	Course Title	Credits	
			CHEM225	Analytical Chemistry	4	
			CHEM253	Organic Chemistry III	4	
				Chemistry Electives*	12	
Total		24	Total		20	

*The electives cannot count toward the student's major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits	Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors Environmental Certificate for Chemistry and Biochemistry Majors			
CHEM111	General Chemistry I	4				
CHEM113	General Chemistry II	4				
CHEM115	General Chemistry III	4				
CHEM225	Analytical Chemistry	4	Course Number	Course Title	Credits	
CHEM251	Organic Chemistry I	4	CHEM225	Analytical Chemistry		
CHE264	Introduction to Environmental Science	4	or	Organic Chemistry III	4	
CHEM 371	Environmental Analytical Chemistry	4	CHEM253			
CHEM 465	Energy and the Environment	4	CHEM330	Biochemistry		
Total		32	or	Physical Chemistry I	4	
			CHEM361			
			CHEM303	Chemical Engineering Thermodynamics	4	
			CHE264	Introduction to Environmental Science	4	
			CHEM 371	Environmental Analytical Chemistry	4	
			CHEM 465	Energy and the Environment	4	
			Total		24	



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society’s need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department's Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department’s Program Educational Objectives and Student Learning Outcomes*

Program Educational Objectives

- I. Graduates will demonstrate the ability to perform essential engineering functions in the design, management, or construction industry.
- II. Graduates will demonstrate the ability to design/construct complex engineering systems in the broad-based engineering industry.
- III. Graduates will demonstrate their potential for technical leadership and management.

Student Learning Outcomes

- A. Technical Core - Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
- B. Experiments - Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.
- C. Engineering Problems - Develop problem statements and solve well-defined engineering problems in four

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

- technical areas appropriate to civil engineering.
- D. Engineering Impact - Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
 - E. Contemporary Issues - Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.
 - F. Design - Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
 - G. Multidisciplinary - Function effectively as a member of a multidisciplinary team.
 - H. Professional/Ethical - Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
 - I. Communication - Organize and deliver effective verbal, written, and graphical communications.
 - J. Engineering Tools - Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.
 - K. Life Long Learning - Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
 - L. Leadership - Apply leadership principles to direct the efforts of a small group.
 - M. Service - Use one's time and skills to benefit an individual or community without cost to the recipient.
 - N. Project Management - Explain key concepts in project management, and develop solutions to well-defined project management problems.
 - O. Business and Public Administration - Explain key concepts and processes used in business, public policy, and public administration.
 - P. Cultural and Global Awareness - Analyze and interpret cultural perspectives and social systems that define human characteristics.

*The civil engineering program uses the term "educational objective" to describe the expected accomplishments of our students in three to five years following graduation. The term "student learning outcome" is used to describe knowledge and skills at the time of graduation.

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

Civil Engineering PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
MA 111	Calculus I	5	MA 211	Differential Equations	4
PH 111	Physics I	4	CHEM 111	General Chemistry I	4
RH 131	Rhetoric and Composition	4	EM 202	Dynamics	4
	or			Elective(HSS)	
HSS	Elective		CE 201	Engineering Surveying II	2
CLSK 100	College & Life Skills	1		Total	18
EM 104	Graphical Communications	2	Winter Term		Credit
	Total	16	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
MA 112	Calculus II	5	EM 203	Mechanics of Materials	4
PH 112	Physics II	4	CHEM 113	General Chemistry II	4
RH 131	Rhetoric and Composition	4	HSS	Elective	4
	or			Total	16
HSS	Elective		Spring Term		Credit
CE 110	Computer Applications	4	MA 223	Statistics for Engineers	4
	and GIS		EM 301	Fluid Mechanics	4
	Total	17	CE 250	Sustainable Civil	2
Spring Term		Credit		Engineering Design	
MA 113	Calculus III	5	CE 320	C.E. Materials	4
EM 103	Introduction to Design	2		Total	14
EM 120	Engineering Statics	4			
CE 101	Engineering Surveying I	2			
	Elective(Science)	4			
	Total	17			
			Junior Year		
			Fall Term		Credit

CE 321	Structural Mechanics I	4
CE 336	Soil Mechanics	4
ME 201	Thermodynamics	4
	or	
CHE 201	Conservation Principles and Balances	
CE 371	Hydraulic Engineering	4
	Total	16
Winter Term		Credit
ECE 206	Elements of Electrical Eng.	4
	or	
CHE 202	Basic Chemical Process Calculations	
CE 441	Construction Engineering	2
CE 432	Concrete Design I	3
CE 471	Water Resources Engineering	4
	Elective(Science)	4
	Total	17
Spring Term		Credit
CE 310	Civil Engineering Numerical Methods	2
CE 431	Steel Design I	3
CE 460	Environmental Engineering	4
RH 330	Technical and Professional Communication	4
CE 461	Environmental Engineering Lab	2
	Total	15

Senior Year		
Fall Term		Credit
CE 486	C.E. Design & Synthesis I	2
	*Elective(Technical)	4
CE 450	C.E. Codes & Regulations	4
	Elective(HSS)	4
	Elective(HSS)	4
	Total	18
Winter Term		Credit
CE 487x	Technical System Design & Synthesis	2
CE 488	C.E. Design & Synthesis II	2
CE	**C.E. Elective	4
	*Elective(Technical)	4
CE 303	Engineering Economy	4
	Total	16
Spring Term		Credit
CE 489	C.C.E. Design & Synthesis III	2
	*Elective(Technical)	4
	Elective(HSS)	4
	Elective(HSS)	4
CE 400	Career Preparation Seminar	0
	Total	14
Total credits required:		194

*A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, or physics.

****Student shall choose 1 of the following courses as the CE elective:**

- CE 421 Structural Mechanics II**
- CE 442 Cost Engineering**
- CE 563 Unit Operations in Environmental Engineering**

Environmental Engineering Area Minor

The Environmental Engineering Area minor includes 6 required courses and 8 elective credit hours. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their interests.

The 6 required courses are as follows:

- CE 460 Introduction to Environmental Engineering
- CE 471 Water Resources Engineering
- CHEM 264 Introduction to Environmental Science
- CE 563/CHE 461 Unit Operations in Environmental Engineering
- CE 564 Aquatic Environmental Chemistry
- CHEM 251 Organic Chemistry I

- CHEM 251L Organic Chemistry I Laboratory

And 8 credit hours from the following courses:

- CE 561/CHE 450 Air Pollution Control
- CE 562 Treatability Studies
- CE 565 Solid and Hazardous Waste Regulation and Treatment
- CE 566 Environmental Management
- CE 567 Applied Hydrologic Modeling
- CE 568 Applied Contaminant Transport Modeling
- CE 569 Environmental Systems Optimization
- CE 573 Groundwater Analysis
- CE 590 Special Problems
- CE 598 Stream Restoration (Environmental River Mechanics)
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- AB 320 Ecology and Environmental Biology

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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. practice their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment
2. continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods
3. function independently and in leadership positions in multidisciplinary teams
4. perform effectively within their profession, their community, and in the public service arena

CPE student outcomes

At the time of graduation, students will have demonstrated :

1. an ability to apply knowledge of mathematics, science, and engineering
2. an ability to design and conduct experiments, as well as to analyze and interpret data
3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
4. an ability to function on multidisciplinary teams
5. an ability to identify, formulate, and solve engineering problems
6. an understanding of professional and ethical responsibility
7. an ability to communicate effectively
8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context
9. a recognition of the need for, and an ability to engage in life-long learning
10. a knowledge of contemporary issues
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The computer engineering program is accredited by the Engineering Accreditation Commission of ABET,www.abet.org

COMPUTER ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term		Credit	Fall Term		Credit
PH 111	Physics I	4	MA 211	Differential Equations	4
MA 111	Calculus I	5			

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

CLSK 100	College & Life Skills	1	CSSE 232	Computer Architecture I	4
RH 131	Rhetoric and Composition	4	ECE 203	DC Circuits	4
	or		CHEM 111	General Chemistry I	4
HSS	Elective			Total	16
ECE 160	Engineering Practice	2	Winter Term		Credit
	Total	16	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
PH 112	Physics II	4	CSSE 332	Operating Systems	4
MA 112	Calculus II	5	ECE 204	AC Circuits	4
CSSE 120	Introduction to	4	HSS	Elective	4
	Software Development			Total	16
RH 131	Rhetoric and Composition	4	Spring Term		Credit
	or		MA 381	Introduction to Probability	4
HSS	Elective			with Applications	
	Total	17		to Statistics	
Spring Term		Credit	ECE 332	Computer Architecture II	4
PH 113	Physics III	4	ECE 205	Dynamical Systems	4
MA 113	Calculus III	5	HSS	Elective	4
ECE 130	Introduction to	4		Total	16
	Logic Design				
CSSE 220	Object-Oriented	4			
	Software Development				
	Total	17			

Junior

Year

Fall Term		Credit
MA 275	Discrete & Combinational	4
	Algebra I	
ECE 250	Electronic Device Modeling	4
ECE 300	Continuous-Time Signals	4
	Systems	
RH 330	Technical and Professional	4
	Communication	
	Total	16
Winter Term		Credit
ECE 380	Discrete-Time Signals Systems	4
ECE 331	Embedded System Design	4
ECE 351	Analog Electronics	4
	Math/Science Elective	4
	Total	16
Spring Term		Credit
ECE 333	Digital Systems	4
ECE 342	Introduction to	4
	Electromagnetic	
	Compatibility	
ECE 362	Principles of Design	3
HSS	Elective	4
	Total	15

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
	Total	15
Winter Term		Credit
ECE 461	Engineering Design II	4

	Tech Elective	4
	Area Elective	4
HSS	Elective	4
	Total	16
<i>Spring Term</i>		<i>Credit</i>
ECE 462	Engineering Design III	2
	Area Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
	Total	18
Total credits required:		194

AREA ELECTIVES

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

TECH ELECTIVE

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, geology or physics course as a math science elective except those courses that are cross-referenced with any engineering courses.

COMPUTER ENGINEERING CORE COURSES

SECOND MAJOR IN COMPUTER ENGINEERING

Course Number	Course Title	Credits	The ECE Department will not allow the following second major combinations:																																									
ECE130	Introduction to Logic Design	4	1. Degree in Electrical Engineering and a Second Major in Computer Engineering. 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.																																									
ECE160	Engineering Practice	2																																										
ECE203	DC Circuits	4																																										
ECE204	AC Circuits	4																																										
ECE205	Dynamical Systems	4																																										
ECE250	Electronic Device Modeling	4	Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.																																									
ECE300	Continuous-Time Signals Systems	4																																										
ECE331	Embedded System Design	4	<table><tr><th>Course Number</th><th>Course Title</th><th>Credits</th></tr><tr><td>ECE130</td><td>Introduction to Logic Design</td><td>4</td></tr><tr><td>ECE203</td><td>DC Circuits</td><td>4</td></tr><tr><td>ECE204</td><td>AC Circuits</td><td>4</td></tr><tr><td>ECE205</td><td>Dynamical Systems</td><td>4</td></tr><tr><td>ECE250</td><td>Electronic Device Modeling</td><td>4</td></tr><tr><td>ECE300</td><td>Continuous-Time Signals Systems</td><td>4</td></tr><tr><td>ECE331</td><td>Embedded System Design</td><td>4</td></tr><tr><td>ECE332</td><td>Computer Architecture II</td><td>4</td></tr><tr><td>ECE333</td><td>Digital Systems</td><td>4</td></tr><tr><td>ECE342</td><td>Introduction to Electromagnetic Compatibility</td><td>4</td></tr><tr><td>ECE351</td><td>Analog Electronics</td><td>4</td></tr><tr><td>ECE380</td><td>Discrete-Time Signals and</td><td>4</td></tr></table>	Course Number	Course Title	Credits	ECE130	Introduction to Logic Design	4	ECE203	DC Circuits	4	ECE204	AC Circuits	4	ECE205	Dynamical Systems	4	ECE250	Electronic Device Modeling	4	ECE300	Continuous-Time Signals Systems	4	ECE331	Embedded System Design	4	ECE332	Computer Architecture II	4	ECE333	Digital Systems	4	ECE342	Introduction to Electromagnetic Compatibility	4	ECE351	Analog Electronics	4	ECE380	Discrete-Time Signals and	4		
Course Number	Course Title	Credits																																										
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ECE331	Embedded System Design	4																																										
ECE332	Computer Architecture II	4																																										
ECE333	Digital Systems	4																																										
ECE342	Introduction to Electromagnetic Compatibility	4																																										
ECE351	Analog Electronics	4																																										
ECE380	Discrete-Time Signals and	4																																										
ECE332	Computer Architecture II	4																																										
ECE333	Digital Systems	4																																										
ECE342	Introduction to Electromagnetic Compatibility	4																																										
ECE351	Analog Electronics	4																																										
ECE362	Principles of Design	3																																										
ECE380	Discrete-Time Signals and Systems	4																																										
ECE460	Engineering Design I	3																																										
ECE461	Engineering Design II	4																																										
ECE462	Engineering Design III	2																																										

the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science

The Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The computer science curriculum is designed to prepare students for multiple careers in a rapidly changing environment. The department's courses emphasize fundamental concepts and techniques that will last longer than present technology.

Computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer architecture, programming languages, operating systems, and software engineering. Majors also complete important courses in closely related fields, e.g., discrete mathematics, digital logic design, and probability and statistics. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Courses in database systems, compilers, computer graphics, fractals and chaotic dynamical systems, artificial intelligence, theory of computation, analysis of algorithms, computer networks, computer vision, web-based information systems, and cryptography are available as advanced electives. A three-term senior project provides valuable practical experience in the specification, design, implementation, and documentation of large software systems. Qualified students can undertake independent study in advanced topics in computer science, participate in a research project with a faculty member, or complete a senior thesis.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

Computer science majors have diverse interests and career goals. Five free elective courses allow students to tailor their undergraduate education to their specific goals. Students planning to undertake graduate study in computer science usually take additional advanced courses in computer science, electrical engineering, and mathematics.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Computer science majors have unlimited access to the department's laboratories. Computer science majors are frequently employed by the computing center as user consultants, and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

Computer Science Program Educational Objectives

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

https://www.rose-hulman.edu/course-catalog/course-catalog-2011-2012/programs-of-study/computer-science.aspx[1/20/2017 12:53:24 PM]

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Student Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering
13. Recognize the need for, and engage in, lifelong learning
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

There are many alternatives to the schedule below. Students with special interests or opportunities (e.g., advanced placement) should determine what schedule is best for their own plan of study by examining schedules at the department's web site: www.cs.rose-hulman.edu.

The computer science program is accredited by the Computing Accreditation Commission of ABET, www.abet.org

COMPUTER SCIENCE PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
CSSE 120	Introduction to Software Development	4	CHEM 111	General Chemistry I	4
PH 111	Physics I	4	CSSE 232	Computer Architecture I	4
MA 111	Calculus I	5	MA 212	Matrix Algebra and Systems of Differential Equations	4
CLSK 100	College & Life Skills	1	MA 275	Discrete & Combinatorial Algebra I	4
RH 131	Rhetoric and Composition	4			
	Total	18		Total	16
Winter Term		Credit	Winter Term		Credit
CSSE 220	Object-Oriented Software Development	4	CSSE 230	Data Structures and Algorithm Analysis	4
PH 112	Physics II	4	CSSE 333	Database Systems	4

MA 112	Calculus II	5	MA 375	Discrete & Combinatorial	4
HSS	Elective	4		Algebra II	
	Total	17	HSS	Elective	4
Spring Term		Credit		Total	16
CSSE 132	Introduction to	4	Spring Term		Credit
	Computer Systems		CSSE 304	Programming Lang. Con.	4
MA 113	Calculus III	5	ECE 332	Computer Architecture II	4
HSS	Elective	4	MA 381	Introduction to Probability	4
Science	Elective	4		with Applications	
	Total	17		to Statistics	
			RH 330	Technical and Professional	4
				Communication	
				Total	16

Junior Year					
Fall Term		Credit			
CSSE 371	Software Requirements	4	Senior Year		
	Engineering		Fall Term		Credit
CSSE/MA 473	Design and Analysis	4	CSSE 487	Senior Research Project I	4
	of Algorithms			or	
CSSE	Elective	4	CSSE 497	Senior Project I	
HSS	Elective	4		or	
	Total	16	CSSE 494	Senior Thesis I	
Winter Term		Credit	CSSE	Elective	4
CSSE 332	Operating Systems	4	HSS	Elective	4
CSSE 374	Software Design	4	Free	Elective	4
CSSE/MA 474	Theory of Computation	4		Total	16
HSS	Elective	4	Winter Term		Credit
	Total	16	CSSE 488	Senior Research Project II	4
Spring Term		Credit		or	
CSSE	Elective	4	CSSE 498	Senior Project II	
	Technical Elective	4		or	
Free	Elective	4	CSSE 495	Senior Thesis II	
Free	Elective	4	CSSE	Elective	4
	Total	16	HSS	Elective	4
				Technical Elective	4
				Total	14
			Spring Term		Credit
			CSSE 489	Senior Research Project III	4
				or	
			CSSE 499	Senior Project III	
				or	
			CSSE 496	Senior Thesis III	
			Free	Elective	4
			Free	Elective	4
				Total	12
			Total credits required:		192

CSSE electives cannot include any of CSSE 372, 373, 375, 376, and 477.

Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.

HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

- 1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE132, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112,

MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.

- 2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
- 3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
- 4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
- 5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
- 6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
- 7. A total of 192 credits.

Area Minor in Computer Science

Advisor: Dr. Laxer

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

CSSE120 Introduction to Software Development
CSSE220 Object-Oriented Software Development
CSSE230 Data Structures and Algorithm Analysis
16 additional credits of computer science courses numbered above 200.
None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories

2. use economic theory to define, analyze and solve a wide range of problems.

3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.

4. communicate complex economics topics in both oral and written form.

5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
MA 111	Calculus I	5	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1		Economics Elective	4
RH 131	Rhetoric and Composition	4		*HSS Elective	4
	or			Physical or Life Science	4
HSS	Elective			Total	16
	Physical or Life Science	4	Winter Term		Credit
	Total	14	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
MA 112	Calculus II	5		Economics Elective	4
CSSE 120	Introduction to	4		*HSS Elective	4
	Software Development			Physical or Life Science	4
	Physical or Life Science	4		Total	16
RH 131	Rhetoric and Composition	4	Spring Term		Credit
	or		MA 381	Introduction to Probability	4
HSS	Elective			with Applications	
	Total	17		to Statistics	
Spring Term		Credit	MA 223	Engineering Statistics	4
MA 113	Calculus III	5		Economics Elective	4
SV 151	Principles of Economics	4		*HSS Elective	4

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs


Physical or Life Science	4	Physical or Life Science	4
*HSS Elective		Total	16
Total	17		

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

- 1. 20 credits of required Economics courses:
 - SV151 Principles of Economics
 - IA350 Intermediate Microeconomics
 - IA351 Intermediate Macroeconomics
 - SV450 Introduction to Econometrics
 - XX496 Seminar for HSS Senior Projects
 - XX497 Directed Study for HSS Senior Project
- 2. 24 additional credits in Economics electives.
- 3. 27 credits in required Mathematics courses:
 - MA111, 112, 113 Calculus I, II, III
 - MA211, 212 Differential Equations , and Matrix Algebra and Systems of Differential Equations
 - MA223 Engineering Statistics I or
 - MA381 Introduction to Probability
- 4. 12 additional credits in Mathematics other than MA351-356.
- 5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
- 6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
- 7. 4 credits in Engineering Management
- 8. 4 credits in Computer Science: CSSE 120
- 9. CLSK 100 (1 credit) and SV 200 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
SV 200	1
TOTAL	193



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Programs of Study

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

- 1. practice their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment
- 2. continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods
- 3. function independently and in leadership positions in multidisciplinary teams
- 4. perform effectively within their profession, their community, and in the public service arena

EE student outcomes

At the time of graduation, students will have demonstrated :

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to function on multidisciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context
- a recognition of the need for, and an ability to engage in life-long learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

ELECTRICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
PH 111	Physics I	4	MA 211	Differential Equations	4
MA 111	Calculus I	5	CHEM 111	General Chemistry I	4
CLSK 100	College & Life Skills	1	ECE 203	DC Circuits	4

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

RH 131	Rhetoric and Composition	4	ECE 230	Introduction to	4
	or			Microcontrollers	
HSS	Elective			Total	16
ECE 160	Engineering Practice	2	Winter Term		Credit
	Total	16	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
PH 112	Physics II	4		Math/Science Elective	4
MA 112	Calculus II	5	ECE 204	AC Circuits	4
ECE 130	Introduction to	4	HSS	Elective	4
	Logic Design			Total	16
RH 131	Rhetoric and Composition	4	Spring Term		Credit
	or		MA 381	Introduction to Probability	4
HSS	Elective			with Applications	
	Total	17		to Statistics	
Spring Term		Credit	ECE 205	Dynamical Systems	4
PH 113	Physics III	4	ECE 370	Power & Energy Systems	4
MA 113	Calculus III	5		or	
HSS	Elective	4	ECE 371	Sustainable Energy Systems	
CSSE 120	Introduction to	4	HSS	Elective	4
	Software Development			Total	16
	Total	17			

Junior Year				
Fall Term				Credit
ECE 300	Continuous-Time Signals	4		
	Systems			
ECE 250	Electronic Device Modeling	4		
ECE 340	Electromagnetic Fields	4		
RH 330	Technical and Professional	4		
	Communication			
	Total	16		
Winter Term				Credit
ECE 380	Discrete-Time Signals	4		
	and Systems			
ECE 351	Analog Electronics	4		
ECE 341	Electromagnetic Waves	4		
	Math/Science Elective	4		
	Total	16		
Spring Term				Credit
ECE 310	Communications Systems	4		
ECE 320	Linear Control Systems	4		
ECE 333	Digital Systems	4		
ECE 362	Principles of Design	3		
	Total	15		

Senior Year				
Fall Term				Credit
ECE 460	Engineering Design I	3		
	Tech Elective	4		
	Area Elective	4		
HSS	Elective	4		
	Total	15		
Winter Term				Credit
ECE 461	Engineering Design II	4		
	Tech Elective	4		
	Area Elective	4		

HSS	Elective	4
	Total	16
Spring Term		Credit
ECE 462	Engineering Design III	2
	Area Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
	Total	18
	Total credits required:	194

AREA ELECTIVES

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

TECH ELECTIVE

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

NOTES

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

ELECTRICAL ENGINEERING CORE COURSES

SECOND MAJOR IN COMPUTER ENGINEERING

Course Number	Course Title	Credits	
ECE130	Introduction to Logic Design	4	The ECE Department will not allow the following second major combinations:
ECE160	Engineering Practice	2	
ECE203	DC Circuits	4	1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
ECE204	AC Circuits	4	
ECE205	Dynamical Systems	4	2. Degree in Computer Engineering and a Second Major in Electrical Engineering.
ECE230	Introduction to Microcontrollers	4	
ECE250	Electronic Device Modeling	4	Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.
ECE300	Continuous-Time Signals Systems	4	
ECE310	Communication Systems	4	EE Second Major
ECE320	Linear Control Systems	4	
ECE333	Digital Systems	4	
ECE340	Electromagnetic Fields	4	
ECE341	Electromagnetic Waves	4	
ECE351	Analog Electronics	4	
ECE362	Principles of Design	3	
ECE370 or ECE 371	Power & Energy Systems or Sustainable Energy Systems	3	
ECE380	Discrete-Time Signals and Systems	4	
ECE460	Engineering Design I	3	
ECE461	Engineering Design II	4	
ECE462	Engineering Design III	2	
Course Number	Course Title	Credits	
ECE130	Introduction to Logic Design	4	
ECE203	DC Circuits	4	
ECE204	AC Circuits	4	
ECE205	Dynamical Systems	4	
ECE230	Introduction to Microcontrollers	4	
ECE250	Electronic Device Modeling	4	
ECE300	Continuous-Time Signals Systems	4	
ECE310	Communication Systems	4	
ECE320	Linear Control Systems	4	
ECE333	Digital Systems	4	
ECE340	Electromagnetic Fields	4	

ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE370	Power & Energy Systems	4
	or	
ECE371	Sustainable Energy Systems	
ECE380	Discrete-Time Signals and Systems	4
MA381	Introduction to Probability with Applications to Statistics	4
Total		64

AREA MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Example Area Minor for Computer Science and Software Engineering		
Course Number	Course Title	Credits
ECE203	DC Circuits	4
Required		
ECE204	AC Circuits	4
Required		
ECE205	Dynamical Systems	4
ECE300	Continuous-Time Signals and Systems	4
ECE380	Discrete-Time Signals and Systems	4
ECE310	Communication Systems	4

Example Area Minor for Mechanical Engineering

Areas of Concentration		
Course Number	Course Title	Credits
ECE203	DC Circuits	4
Required		
ECE204	AC Circuits	4
Required		
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution

- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

ENHANCED STUDY IN COMMUNICATION SYSTEMS

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 410 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Continuous-Time Signals Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Dynamical Systems
- ECE300 Continuous-Time Signals Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

ENHANCED STUDY IN POWER SYSTEMS

Power Certificate

Take all of the following courses:

- ECE 571 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines

as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

- 1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
- 2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete-Time Signals and Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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News

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Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Physics

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

EP Educational Objectives

General EP Educational Objectives:

All engineer physics graduates will be employed in industry, graduate school, or volunteer service and will meet the following objectives

- Objective A:
- Exhibit strong skills in problem solving, leadership, teamwork, and communication.
- Objective B:
- Use these skills to contribute to their community and globally.
- Objective C:
- Make thoughtful, well-informed choices in their projects and career.
- Objective D:
- Demonstrate commitment to continuous education of themselves and of others.

EP Education Core Objectives:

- Objective E:
- Effective multi-disciplinary engineers/researchers and be life-long learner.
- Objective F:
- Be educated in the principles of sciences and engineering necessary to understand systems in their concentration.
- Objective G:
- Able to use engineering tools that will allow them to design, analyze, and test systems.
- Objective H:
- Aware of the impact of their work in local and global environment.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

EP Student Learning Outcomes

- Outcome A: Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
- Outcome B1: Interpreting Data: Ability to interpret graphical, numerical, and textual data.
- Outcome B2: System Level Modeling: Ability to model components and system level engineering problems.
- Outcome B3: Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.
- Outcome C: Design: Ability to design a product or process to satisfy client's needs subject to constraints.
- Outcome D: Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
- Outcome E: Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
- Outcome F: Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
- Outcome G: Communication: Ability to communicate effectively in oral, written and visual forms.
- Outcome H: Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Outcome I: Life Long Learning: A facility for independent learning and continued professional development.

ENGINEERING PHYSICS (Micro-Nano)

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
PH 111	Physics I	4	ES 201	Conservation and	4
MA 111	Calculus I	5		Accounting Principles	
CLSK 100	College & Life Skills	1	PH 235	Many Particle Physics	4
RH 131	Rhetoric and Composition	4	MA 211	Differential Equations	4
EM 104	Graphical Communications	2	PH 292	Physical Optics	4
	Total	16		Total	16
Winter Term		Credit	Winter Term		Credit
PH 112	Physics II	4	EP 280	Intro to Nano Engineering	4
MA 112	Calculus II	5	PH 255	Foundations of	4
CHEM 111	General Chemistry I	4		Modern Physics	
CSSE 120	Introduction to	4	MA 212	Matrix Algebra and Systems	4
	Software Development			of Differential Equations	
ME 123	or		ES 202	Fluid & Thermal Systems	3
	Computer Applications I			Total	15
	Total	17	Spring Term		Credit
Spring Term		Credit	HSS	Elective	4
PH 113	Physics III	4	OE 295	Optical Systems	4
MA 113	Calculus III	5	SV 151	Principles of Economics	4
CHEM 113	General Chemistry II	4	ES 203	Electrical Systems	4
OE 172	Optics in Technology*	2		Total	15
EM 103	Introduction to Design**	2			
	Total	17*			
Junior Year					
Fall Term		Credit			
PH 316	Electric and Magnetic Fields	4			
HSS	Elective	4			
PH 405	Semiconductor Materials	4			
	and Applications				
MA 223	Engineering Statistics I	4			
	Total	16			
Winter Term		Credit			
HSS	Elective	4			
PH 317	Electromagnetism	4			
RH 330	Technical and	4			

Professional Communication.		
EP 406	Semiconductor Devices and Fabrication	4
Total		16
Spring Term		Credit
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
EP 410	Intro to MEMS	4
EP 415	Engineering Physics Project I	4
Engineering Elective or		4
EP 408	Microsensors	
Total		16

Senior Year		
Fall Term		Credit
EP 416	Engineering Physics Project II	4
EP 411	Advanced topics in MEMS	4
OE 495	Optical Metrology	4
Engineering Elective		4
Total		16
Winter Term		Credit
EP 417	Engineering Physics Project III	4
HSS	Elective	4
Elective		4
PH 401	Intro Quantum Mechanics	4
Total		16
Spring Term		Credit
HSS	Elective	4
HSS	Elective	4
Science Elective		4
Engineering Elective or		4
EP 408	Microsensors	
Total		16
Total credits required:		193

*If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

EP 415, EP 416, and EP 417 are courses the student can take from any engineering department where the student has an area of concentration. The projects will have industrial clients that emphasize both physics and engineering and it may be jointly administered with the respective departments.

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

SUMMARY OF GRADUATION REQUIREMENTS FOR ENGINEERING PHYSICS

Subjects	#Classes	Hours	
Physics(PH)	10	40	
Math(MA)	6	27	
Chemistry(CHEM)	2	8	1. All the courses listed above by the number.
Computer Science(CSSE)/ME	1/0 or 0/1	4	2. The program must be approved by the EP advisor.
EM	2	4	3. A list of the engineering electives is provided.
CLSK	1	1	4. An engineering elective is any RHIT course in an engineering discipline.
Engineering Science	3	11	
Engineering Science	3	11	5. Science electives are courses that should be taken in the

Optical Engineering (OE)	3	10	physics, chemistry, math, or biology programs.
HSS	9	36	6. A free electives is any course in engineering, science,
Engineering Physics (EP)	6	24	humanities, military science, or air science.
Engineering Physics Project(EP)	3	12	
Elective(Science, Eng. and Free)	4	16	
Total	50	193	
		Classes by Subjects	Hours
		Physics Coursework*	40
		Chemistry and Mathematics Coursework**	35
		Humanities and Social Science(Standard requirement)	36
		Computer Science, EM, CLSK Courses	9
		Engineering Science Classes	11
		Other Engineering Classes (Optical)	10
		EP Courses	24
		EP Projects	12
		Engineering Electives	8
		Science and Free Electives	8
		Total	193

Foundation Physics Classes

Course Description	Hours
PH 235 Many Particle Physics	4
PH 255 Foundations of Modern Physics	4
PH 316 Electric & Magnetic Fields	4
PH 317 Electromagnetism	4
PH 401 Introduction to Quantum Mechanics	4
Total	20

General Foundation Classes

Course Description	Hours
PH 111 Physics I	4
PH 112 Physics II	4
PH 113 Physics III	4
MA 111 Calculus I	5
MA 112 Calculus II	5
MA 113 Calculus III	5
MA 211 Differential Equations	4
MA 212 Matrix Algebra and Systems of Differential Equations	4
MA 223 Engineering Statistics	4
CHEM Engineering Chemistry I 105	4
CHEM Engineering Chemistry II 107	4
Total	47

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	2
OE 172	Optics in Technology	2
ES 201	Conservation and Accounting Principles	4
ES 202	Fluids and Thermal Systems	3
ES 203	Electrical Systems	4
EP 280	Introduction to Nano-engineering	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
EP 411	Advance Topics in MEMS	4
OE 495	Optical Metrology	4

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	4
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Recommended Engineering Electives: Requires the approval of the advisor.
The EP advisory committee can modify this list and add more courses over time.

- ECE 204 AC Circuits
- ECE 205 Dynamic Systems
- ECE 351 Analog Electronics
- ME 424 Composite Materials & Mechanics
- OE 485 Electro-Optics & Applications
- OE 450 Laser Systems
- ME 328 Engineering of Materials

Engineering Elective	8	CHE 315 Materials Science & Engineering
CSSE Computer Programming	4	EP 440/407* Advanced Materials
120/ME 123		
Total	67	* indicates a course that is under development.



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Programs of Study

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Course Descriptions

Minors

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Advanced Placement

Graduate Studies

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Mathematics

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

Program Goals and Objectives

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

Degree Requirements

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
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Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.

MA 376 Abstract Algebra	4 hrs.
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One of the following	4 hrs.
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MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Continuous Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives 12 hrs.

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- MA 493 and MA 494 must be taken in separate terms.

- The requirement of MA 491-492 may be fulfilled through some project experience (such as an internship) and another 300-level or above mathematics course (4 hours), as approved by the project advisor. The course substitution procedure must be used.
- The project must involve work done by the student(s) to solve a problem presented by an external sponsor. The written project submission must be signed by the student's project advisor (who must be a member of the mathematics department) and two additional members (who are approved by the project advisor), and must be presented publicly to the department. The additional members of the committee may include representatives of the sponsor.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team). The written submission must be signed by the student's thesis advisor (who must be a member of the mathematics department) and two additional faculty members (who are approved by the thesis advisor), and must be presented publicly to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.
<hr/>	
Total hours required for graduation	195 hrs.

* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
AB 101 — Essential Biology (or higher-level AB course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	
*** 200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.	24 hrs.

**** CLSK 100 — College and Life Skills	1 hr.
MA 200 Career Preparation	1 hr.

Suggested Schedule

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended basic chemistry course is CHEM 105 unless a student is taking a second major or minor requiring CHEM 111 or credit for CHEM 111 has already been received. If CHEM 111 is taken instead of CHEM 105 then the order of the basic science electives in the freshman and sophomore is the second science course listed. Two science courses are to be taken in the winter quarter of freshman year

MATHEMATICS

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
		Credit			Credit
MA 111	Calculus I	5	MA 211	Differential Equations	4
PH 111		MA 275	4
	Physics I		AB 101	Disc. & Comb. Algebra I ...	4
CHEM111	or	4		Essential Biology (or	
RH 131	General Chemistry I			higher level AB course)	
		PH 113	or	4
HSS	Rhetoric and Composition	4	*CSSE220	Physics III	4
CLSK 100	or	1		4
CSSE 120	HSS			Object-Oriented	4
	Elective.....	4		Software Development..	
	College and Life Skills				16
	Introduction to Software				
	Development.....				
		18			
Winter Term			Winter Term		
		Credit			Credit
MA 112	Calculus	5	MA 212	Matrix Algebra and	
PH 112	II.....			Systems of Differential	4
	Physics II			Equations	4
PH 111	or	4		Science Elective	4
CHEM111	Physics		HSS	4
	I.....		**MA 200	Technical	1
AB 101	General Chemistry I			Elective.....	
	or			HSS	
HSS	Essential Biology (or higher	4		Elective.....	
	level AB course).....			Career	
RH 131	HSS Elective	4		Preparation.....	17
	or				
	Rhetoric & Composition				
		17			
Spring Term			Spring Term		
		Credit			Credit
MA 113	Calculus	5	MA 381	Introduction to Probability..	4
PH 113	III.....		MA 371	Linear Algebra I	4
	Physics III			4
PH 112	or		HSS	Technical Elective	4
				4
				HSS	
				Elective.....	
					16

MA	190 Physics	4
	II.....	
HSS	Contemporary Mathematics	2
		4
	Problems.....	
	HSS	
	Elective.....	
		<hr/>
		15

Junior Year

Fall Term		Credit
MA	MA Elective.....	
	Technical Elective	4
	Technical Elective	4
		4
HSS	HSS Elective	
	or	
RH 330	Technical and Professional Communication.....	4
		<hr/>
		16

Winter Term		Credit
MA	366Functions of a Real Variable	
MA	MA Elective.....	4
	Technical Elective	4
		4
HSS	HSS Elective	
	or	
RH 330	Technical and Professional Communication.....	4
		<hr/>
		16

Spring Term		Credit
MA	MA Elective.....	
		4
MA	MA Elective	4
	Technical Elective	4
		4
HSS	HSS Elective	
	or	
RH 330	Technical and Professional Communication.....	4
		<hr/>
		16

Senior Year

Fall Term		Credit
MA	491 Intro to Math Modeling (2 hours)	
MA	492 Senior Project I (2 hours)	
	or	
MA	496 Senior Thesis I (4 hours)	4
	Free Elective	
	4
HSS	Free Elective	4
	4
	HSS Elective	
	
		<hr/>
		16

Winter Term		Credit
MA	493 Senior Project II (2 hours)	
	or	
MA	497 Senior Thesis II (2 hours)	2
MA	MA Elective	
	4
	Free Elective	4
	4
	Free Elective	4
	
	Free Elective	
	
		<hr/>
		18

Spring Term		Credit
MA	494 Senior Project III (2 hours)	
	or	
MA	498 Senior Thesis III (2 hours)	2
MA	MA Elective	
	4
	Free Elective	4
	4
	Free Elective	
	
		<hr/>
		14

Total credits required: 195

Notes:

- *MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework
- **MA 200 - Career Preparation - may be taken in either the winter or spring quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- Math Elective: A course either required by the concentration or a true math elective.
- Science Elective: Any Physical or Life Sciences elective (not Computer Science) at any level.
- Technical Elective: Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- Free Elective: Any course.

Area Minor in Mathematics

A student, not pursuing a major or second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- Six courses in foundational mathematics
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- Sixteen additional credit hours of "upper division" courses:
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

Area Minor in Computational Science

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the major.
- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

Area Minor in Statistics

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- Globally required mathematics courses
 - MA 111 Calculus I
 - MA 112 Calculus II
 - MA 113 Calculus III
 - MA 212 Differential Equations
- Required Introductory Statistics/Probability Courses:
 - MA 381 Introduction to Probability with Applications to Statistics,

One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is taken before MA223/MA382 the student will be strongly recommended to take MA382.

- Required Second Statistics Course

One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics

- Electives

3 courses (12 credits) selected from the following list, at least two of which must be starred. Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.

MA 385* Quality Methods

MA 386* Statistical Programming

MA 387* Statistical Methods in Six Sigma

MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers

MA 445 Stochastic Models in Operations Research

MA 481* Mathematical Statistics

MA 485* Regression and Time Series Analysis

MA 487* Design of Experiments

MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students
- Only MA111, MA112, MA113, MA212 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Mechanical Engineering

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Since mechanical engineering is a broad field of endeavor, the curriculum offers a strong technical elective program to allow each student to craft a broad educational experience and to develop the flexibility to pursue diverse career goals.

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Design Processes and Methodology.

The strength of any department is its faculty. The mechanical engineering faculty is committed to providing a dynamic and innovative learning environment and to maintaining and increasing their technical competence in a rapidly changing world. Stereotypes notwithstanding, they understand that people are more important than things. Thus, they encourage each student to seek them out when he or she has academic problems or needs guidance in career planning.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 12 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

Vision: To graduate the best baccalaureate mechanical engineers.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Learning outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

- a. *an ability to apply knowledge of mathematics, science, and engineering*
- b. *an ability to design and conduct experiments, as well as to analyze and interpret data*
 1. *Identify the problem and develop an appropriate experimental approach*
 2. *Select measurement techniques to collect appropriate experimental approach.*
 3. *Estimate experimental uncertainties.*
 4. *Collect and present data in an accurate and orderly way.*
 5. *Use appropriate statistical procedures to analyze and evaluate the information contained in a data set.*
 6. *Analyze the data and draw supportable conclusions from the result*
- c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
 1. *Understand the problem.*
 2. *Develop a design specification that addresses customer/client needs and constraints.*
 3. *Carry out a conceptual design by generating multiple solutions that address the requirements of the design specification.*
 4. *Evaluate the feasibility of the solutions.*
 5. *Choose an appropriate solution and justify that solution*
 6. *Carry out a conceptual-level design using appropriate design tools and methodologies.*
 7. *Test and refine the implementation until the product or process design specifications are met or exceeded.*
 8. *Document the finished product or process as appropriate for the discipline according to standard practice.*
- d. *an ability to function on multi-disciplinary teams*
 1. *Demonstrate how you reached a decision as a team.*
 2. *Describe the team role you filled and how that contributed to the final project.*
 3. *Listen openly, actively, and critically.*
- e. *an ability to identify, formulate, and solve engineering problems*
 1. *Inspect and define the problem.*
 2. *Identify the basic principles and concepts that apply to the situation.*
 3. *Build appropriate model(s).*
 4. *Solve the problem by choosing appropriate tools (analytical, experimental, and computational).*
 5. *Check a solution using appropriate criteria.*
- f. *an understanding of professional and ethical responsibility*
 1. *Explain important ethical obligations associated with your discipline.*
 2. *Apply a systematic ethical framework to an ethical issue or situation in a disciplinary context.*
- g. *an ability to communicate effectively*
 1. *Provide a substantive critique that includes recommendations for improvements.*
 2. *Adapt technical information for a non-specialized audience.*
 3. *Convey information effectively through visual media.*
 4. *Present information visually using drawings, graphs and sketches.*
 5. *Deliver oral presentations with clarity and professionalism.*

- h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
 - 1. Engage in the arts (music, theater, art, dance, creative writing, etc.)*
 - 2. Analyze patterns, dynamics, or values of human interaction in social or cultural systems.*
 - 3. Analyze beliefs, backgrounds, cultures, or societies different from your own.*
 - 4. Interpret cultural artifacts and/or ideas in philosophy, the arts, or the sciences.*
- i. a recognition of the need for, and an ability to engage in life-long learning*
 - 1. Students will describe how their current state of performance in an ability has already impacted or might in the future negatively impact their project or team.*
 - 2. Students will describe steps they will follow to reach their desired performance level in the ability.*
 - 3. Students will describe evidence that indicates that they have achieved their professional development goal.*
 - 4. Students will describe the “most significant” professional development they achieved and explain its impacts.*
 - 5. Students will explain what they have learned about the professional development process that will transfer into life after graduation.*
- j. a knowledge of contemporary issues*
 - 1. Students will identify the problem.*
 - 2. Students will describe the problem from different perspectives (At least two sides)*
 - 3. Students will identify stakeholders and describe how stakeholders are affected*
 - 4. Students will justify arguments logically.*
 - 5. Students will reference sources appropriately.*
- k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

Area Minor*** in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

ME 301 Thermodynamics II
CHE 303 Chem. Engineering Thermodynamics
ME 302 Heat Transfer
CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems
ME 407 Power Plants**
ME 408 Renewable Energy
ME 409 Air Conditioning*
ME 410 Internal Combustion Engines
ME 411 Propulsion Systems**
ME 426 Turbomachinery

Thermal Fluid Sciences
ME 401 Foundation of Fluid Mechanics
ME 402 Advanced Heat Transfer*
ME 405 Theoretical Aerodynamics

ME 427 Computational Fluid Dynamics
ME 501 Advanced Thermodynamics**
ME 502 Topics in Heat Transfer*
ME 503 Viscous Fluid Flow
ME 510 Gas Dynamics
EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

**Requires one of the thermodynamics prerequisites from section 2 above.

* Requires one of the heat transfer prerequisites from section 2 above.

*** ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may include special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

ECE/ME 497 Introduction to Model-Based System Design
ECE/ME 497 Advanced Model Based-System Design

Elective Courses

CHEM 470 Combustion Chemistry

ECE 320 Linear Control Systems

or

ME 406 Control Systems

ECE 420 Nonlinear Control Systems

or

ME 506 Advanced Control Systems

ECE 370 Machines & Power

ECE 410 Communication Networks

ECE 452 Power Electronics

ME 408 Renewable Energy

ME 410 Internal Combustion Engines

ME 411 Propulsion Systems

ME 422 Finite Elements for Engineering Applications

ME 427 Introduction to Computational Fluid Dynamics

ME 450 Combustion

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

MA 336 Boundary Value Problems

ME 405 Theoretical Aerodynamics

ME 401 Foundation of Fluid Mechanics

ME 411 Propulsion Systems

ME 422 Intro to Finite Element Fundamentals

ME 426 Turbomachinery

ME 427 Introduction to Computational Fluid Dynamics

ME 461 Aerospace Design

ME 503 Viscous Flow

ME 510 Gas Dynamics

ME 512 Light Weight Structures

ME 522 Advanced Finite Element Analysis

PH 322 Celestial Mechanics

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

CE 561 or CHE 450 Air Pollution (cross-listed class)

CE 590 Climate Change Assessment

CHE 490 Energy and Environment

CHE 512 Petrochemical Processes

ECE 370 Power and Energy Systems

ECE 371 Industrial Power Systems

ME 407 Power Plants

ME 408 Renewable Energy

ME 450 Combustion

ME 501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma

Engineering Management List

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 520 Accounting for Technical Managers
- EMGT 521 Financial Management in a Technical Environment
- EMGT 522 Organizational Management
- EMGT 523 Marketing Issues in a Technical Environment 4
- EMGT 524 Production/Operations Management
- EMGT 526 Technology Management and Forecasting
- EMGT 527 Project Management
- EMGT 531 Economics for Technical Managers
- EMGT 532 Technical Entrepreneurship
- EMGT 533 Intercultural Communication
- EMGT 534 Management Science
- EMGT 535 Strategies for Organizational Change
- EMGT 586 Supply Chain Management
- EMGT 587 Systems Engineering
- EMGT 588 Quality Management I
- EMGT 589 Manufacturing Systems

Humanities, Social Sciences List

- GS 350 International Trade
- GS 351 International Finance
- IA 230 Fundamentals of Public Speaking
- SV 151 Principles of Economics
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- IA 352 Game Theory
- SV 303 Business and Engineering Ethics
- SV 304 Bioethics
- SV 352 Money & Banking
- SV 353 Industrial Organization
- SV 354 Environmental Economics
- SV 356 Corporate Finance
- EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 588 Quality Management
- EMGT 589 Manufacturing Systems
- MA 385 Quality Methods
- ME 317 Design for Manufacturing
- ME 417 Advanced Materials Engineering
- ME 435 Robotics
- ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics
- ME 502 Topics in Heat Transfer

- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the ****Thermal Fluid Systems****list and at least two courses are taken from the ****Thermal Fluid Sciences****list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

MECHANICAL ENIGNEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
MA 111	Calculus I	5	MA 211	Differential Equations	4
PH 111	Physics I	4	ES 201	Conservation &	4
CLSK 100	College & Life Skills	1		Accounting Principles	
EM 104	Graphical Communications	2	ES 203	Electrical Systems	4
RH 131	Rhetoric and Composition	4	HSS	Elective	4
	split fall or winter with			Total	16
HSS	Elective		Winter Term		Credit
	Total	16	MA 212	Matrix Algebra and Systems	4
Winter Term		Credit		of Differential Equations	
MA 112	Calculus II	5	ES 202	Fluid & Thermal Systems	3
PH 112	Physics II	4	ES 204	Mechanical Systems	3
ME 123	Computer Applications I	4	CHEM 111	General Chemistry I	4
RH 131	Rhetoric and Composition	4	HSS	Elective	4
	split fall or winter with			Total	18
HSS	Elective		Spring Term		Credit
	Total	17	MA 223	Statistics for Engineers	4
Spring Term		Credit	ES 205	Analysis & Design of	4
MA 113	Calculus III	5		Engineering Systems	
PH 113	Physics III	4	CHEM 113	General Chemistry II	4
EM 103	Introduction to Design	2	HSS	Elective	4
EM 121	Statics and Mechanics	4		Total	16
	of Materials I				
	Total	15			
Junior					
Year					
Fall Term			Credit		
ME 301	Thermodynamics II			4	
EM 204	Statics and Mechanics			4	
	of Materials I				
ECE 207	Elements of Electrical Engrg II			4	
*Free	Elective			4	
	Total			16	
Winter Term			Credit		
ME 317	Design for Manufacturing	(3)		3	
ME 321	Measurement Systems			4	
	split winter or spring with				
ME 323	Computer Applications II	(2)			
Science	Elective			(4)	
ME 328	Materials Engineering	(4)		4	
RH 330	Technical Communications	(4)			

	split winter or spring with		
HSS	Elective	4	
	Total	(17) or	
		15	
Spring Term		Credit	
ME 302	Heat Transfer	(4)	4
ME 323	Computer Applications II		2
Science	Elective		4
	split winter or spring with		
ME 321	Measurement Systems	(4)	
ME 470	Engineering Design Proc & Method		3
ME 480	split Jr. spring or Sr. fall with Machine Component Design	(4)	
HSS	Elective	(4)	
	split winter or spring with		
RH 330	Technical Communications	4	
	Total	(16) or	
		17	
Senior Year			
Fall Term		Credit	
ME 430	Mechatronic Systems		4
	split fall or winter with		
ME 421	M.E. Lab and *Tech Elective	(2+4)	
ME 406	Control Systems		4
	or		
EM 406	Vibration Analysis	(4)	
ME 480	Machine Component Design		4
	split Jr. spring or Sr. fall with		
ME 470	Engineering Design Proc & Method	(3)	
*Tech	Elective	(4)	4
	Total	(17) or	16
Winter Term		Credit	
ME 471	Capstone Design I	(3)	3
ME 421	M.E. Lab and *Tech Elective		2+4
	split fall or winter with		
ME 430	Mechatronic Systems	(4)	
HSS	Elective	(4)	4
*Free	Elective	(4)	4
	Total	(15) or	17
Spring Term		Credit	
ME 472	Capstone Design II		3
*Tech	Elective		4
**Adv. Tech	Elective		4
HSS	Elective		4
	Total		15
Total credits required:			194

*24 credit hours. in electives composed of 16 cr. hrs. in technical electives, of which at least 4 cr. hrs. must be in advanced level courses and 8 cr. hrs. in free electives. (i.e. 12 cr. hrs. tech. electives, 4 cr. hrs. adv. tech elective, 8 cr. hrs. free electives)

** An advanced technical elective is designated with an * in the undergraduate bulletin ME and EM course description section or any 500 level course and above in BE, ChE, CE, CPE, EE, ME, OE or SE programs. A technical elective is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A science elective is any course in applied biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>

OE Program Education Objectives

Optical Engineering Program Educational Objectives

General Optical Engineering Educational Objectives

All optical engineers will be employed in industry, graduate school, or volunteer service and will meet the following objectives

- They will:
- Objective A:

Objective B:

Objective C:

Objective D:
- Exhibit strong skills in problem solving, leadership, teamwork, and communication

Use their education and experience (life-long learning) to better society

Make thoughtful, ethical, well-informed choice in their projects and career

Be aware of the impact of their work in local and global environment, society, and human

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

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Optical Engineering Core Educational Objectives

- Optical Engineering graduates will be:
- Objective E: Effective multidisciplinary optical engineers/researchers
 - Objective F: Educated in the principles of optical science and engineering necessary to understand optical systems
 - Objective G: Able to use optical engineering and engineering tools to innovate in an enabling technology

OE Student Learning Outcomes

- Outcome A: Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering
- Outcome B1: Interpreting Data: Ability to interpret graphical, numerical, and textual data
- Outcome B2: System Level Modeling: Ability to model components and system optical engineering problems
- Outcome B3: Experimentation:Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before
- Outcome C: Design: Ability to design a product or process to satisfy client's needs subject to constraints
- Outcome D: Team work: Ability to work in multi-disciplinary teams and understand the effective team dynamics and be able to deliver a product
- Outcome E: Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world optical engineering problems
- Outcome F: Professional Practice and Ethics: A sound understanding what an optics professional is and have an awareness and understanding of professional ethics
- Outcome G: Communication: Ability to communicate effectively in oral, written and visual forms
- Outcome H: Contemporary issues and global awareness: An awareness of contemporary issues in engineering profession and the role of professionals in an interdependent global society
- Outcome I: Life Long Learning: A facility for independent learning and continued professional development

The optical engineering program is accredited by the Engineering Accreditation Commission of ABET www.abet.org

Optical Engineering

Freshman Year

Fall Term				Credit
A	111	Calculus I		5
PH	111	Physics I		4
CLSK	100	College and Life Skills		1
RH	131	Rhetoric and Composition		4
EM	104	Graph Comm		2
				16

Winter Term				Credit
PH	112	Physics II		4
MA	112	Calculus II		5
CHEM	111	General Chemistry I		4
ME	123	Computer Applications I		4
				17

Spring Term				Credit
PH	113	Physics III		4
MA	113	Calculus III		5

Sophomore Year

Fall Term			Credit
MA	223	Engineering Statistics	4
or			
SV	151	Principles of Economics	
PH	235	Many-Part Physics	4
MA	211	Differential Equations	4
PH	292	Physical Optics	4
			16

Winter Term				Credit
ECE	203	DC Circuits		4
PH	255	Fnd. of Mod. Phys.		4
Matrix Algebra and Systems of				
MA	212	Differential Equations		4
OE	280	Paraxial Optics		4
				16

Spring Term				Credit
		Free Elective		4
OE	295	Optical Systems		4
SV	151	Principles of Economics		4
		or		
MA	223	Engineering Statistics		

CHEM	113	General Chemistry II	4	ECE	204	AC Circuits	4
OE	172	Optics in Tech	2				
EM	103	Intro Eng. Design	2				16
			17				

Junior Year

Fall Term

Credit

PH	316	Elec & Mag Fields	4
OE	360	Optical Materials and Opto-Mechanics	4
PH	405	S.C. Mat & Appl.	4
ECE	205	Dynamical Systems	4
			16

Winter Term

Credit

OE	393	Fiber Opt & App	4
		Free Elective	4
EP	406	SC Dev & Fab	4
HSS		Elective	
		or	4
RH	330	Technical and Professional Communication	

Spring Term

Credit

OE	415	Opt Eng Des I	4
HSS		Elective	4
HSS		Elective	
		or	4
RH	330	Technical and Professional Communication	
OE	450	Laser Systems	4
			16

If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

Summary of Graduation Requirements For Optical Engineering

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects

Hours

Optics Coursework	46
Physics Coursework	20
Freshmen Physics, Chemistry and Mathematics Coursework	47

Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous	25
Total	194

Physics Classes

Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4
PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM105	Engineering Chemistry I	4
CHEM107	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
EP 406	Semiconductor Devices and Fabrication	4
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
Total		25

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research

PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required Courses

Course	Hours	Course Description
OE 280	4	Paraxial Optics
PH 292	4	Physical Optics
OE 295	4	Optical Systems

Plus at least two courses from one of the areas listed below:

Lens Design Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 480	4	Lens Design and Aberrations
OE 490	4	Directed Research (4 Credits Only)
Photonics/Electro-optics Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-optics and Applications
OE 490	4	Directed Research (4 credits only)
OE 493	4	Fundamentals of Optical Fiber Communications
Image Processing Area		
Course	Hours	Course Description
OE 415	4	Optical Engineering Design I
OE 490	4	Directed Research (4 Credits Only)
PH 437/ECE 480	4	Introduction to Image Processing
PH 537/ECE 582	4	Advanced Image Processing

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)

Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203	4	DC Circuits
ECE 204	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman. All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

Physics

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
MA	111	Calculus I	5			Free Elective†	4
PH	111	Physics I	4	PH	235	Many Particle Physics	4
CLSK	100	College and Life Skills	1	MA	211	Differential Equations	4
RH	131	Rhetoric and Composition		PH	292	Physical Optics	4
		or	4				16
HSS		Elective					
EM	104	Graphical Communications	2				
			16				
Winter Term				Winter Term			
			Credit				Credit
PH	112	Physics II	4	PH	255	Fund. of Modern Physics	4
MA	112	Calculus II	5			Elective	4
CHEM	111	General Chemistry I	4	HSS		Technical Elective	4
		Computing Elective*	2-4			Matrix Algebra and Systems of	
			15 or 17	MA	212	Differential Equations	4
							16
Spring Term				Spring Term			
							Credit
				PH		Theoretical Mechanics I	

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

- Additional Programs of Study
- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

			Credit	HSS	Elective	4
				MA 371	Linear Algebra I	4
PH 113	Physics III	4			Math Elective†	4
MA 113	Calculus III	5				16
CHEM 113	General Chemistry II	4				
HSS	Elective					
	or	4				
RH 131	Rhetoric and Composition					
		17				
Junior Year			Senior Year			
Fall Term			Fall Term			Credit
			Credit			
HSS	Elective	4	Math	Elective†	4	
PH 316	Electric and Magnetic Fields	4		Technical Elective†	4	
	Technical Elective†	4	HSS	Elective	4	
PH 405	Semiconductor Materials and Applications	4		Free Elective	4	
		16			16	
Winter Term			Winter Term			Credit
			Credit			
PH 317	Electromagnetism	4	PH 425	Advanced Physics Lab II	4	
PH 401	Intro Quantum Mechanics	4	HSS	Elective	4	
HSS	Elective	4		Technical Elective†	4	
	Physics Elective†	4		Free Elective†	4	
		16			16	
Spring Term			Spring Term			Credit
			Credit			
PH 325	Advanced Physics Lab I	4	OE 450	Technical Elective†	4	
HSS	Elective	4		Laser Sys & App		
OE 450	Laser Sys & App			or	4	
	or	4		Physics Elective		
	Physics Elective†			Free Elective	4	
PH 327	Thermodynamics & Statistical Mechanics	4		Physics Elective†	4	
		16			16	

Total credits required: 192

* Computing elective: 2 or 4 credit course on computing from the following course: AB 140, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

SUMMARY OF GRADUATION REQUIREMENTS FOR PHYSICS MAJORS

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
6. Sixteen credits of free electives (cannot include ECE340).
7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
8. A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.
9. A free elective is any course offered at RHIT.

Course by Subjects Hours

Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
PH 215	Introduction to Chaos	2
PH 231	Intro to Astronomy and Astrophysics	4
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 322	Celestial Mechanics and Solar	4
PH 330	Material Failure	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
PH 407	Solid State Physics	4
PH 437	Introduction to Image Processing	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	Arranged
PH 470	Directed Research	Arranged
PH 480	Seminar	Arranged
PH 490	Directed Research	Arranged
PH 497+	Senior Thesis	Arranged
PH 498+	Senior Thesis	Arranged
PH 499+	Senior Thesis	Arranged
PH 512	Methods of Mathematical Physics	4
PH 514	Quantum Mechanics	4
PH 530	Advanced Acoustics	4
PH 537	Advanced Image Processing	4
PH 538	Introduction to Neural Networks	4

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year for a total number of 8 credit hours over the three quarter sequence. Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

**Math and Chemistry Courses:

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	
	Linear Algebra	4
MA 371	General Chemistry I	4

CHEM 111	General Chemistry II	4
CHEM 113		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

Area Minor Programs

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus 12 credit hours from the following courses:

Course	Course Title	Hours
PH 270/470	Special Topics in Physics †	ARR
PH 290/490	Directed Research †	ARR
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	2
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4
PH 460	Directed Study †	ARR

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4
PH 290/490	Directed Research	2

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4
PH 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4

PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
PH 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer

Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/physics.aspx>



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

Graduates from the software engineering program will be prepared for many types of careers in software development. In the early phases of their careers, we expect Rose-Hulman software engineering graduates to be able to:

- 1. Develop complex systems (including analysis, design, construction, maintenance, quality assurance and project management) using the appropriate theory, principles, tools and processes.
- 2. Use appropriate computer science and mathematics principles in the development of software systems.
- 3. Solve problems in a team environment through effective use of written and oral communication skills.
- 4. Have knowledge of current issues presently involved in effectively performing duties as a software practitioner in an ethical and professional manner for the benefit of society.
- 5. Practice the lifelong learning needed in order to keep current as new issues emerge.
- 6. Develop software in at least one application domain.

Software Engineering Student Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

The software engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

SOFTWARE ENGINEERING

Freshman Year

<i>Fall Term</i>		<i>Credit</i>
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric & Composition	4
CLSK 100	College and Life Skills	1
		18
<i>Winter Term</i>		<i>Credit</i>

Sophomore Year

<i>Fall Term</i>		<i>Credit</i>
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
		16
<i>Winter Term</i>		<i>Credit</i>

CSSE	220	Object-Oriented Software Development	4	CSSE	230	Data Structures and Algorithm Analysis	4
MA	112	Calculus II	5	CSSE	333	Database Systems	4
PH	112	Physics II	4	MA	375	Discrete & Combinatorial Algebra II	4
HSS		Elective	4			Domain track course	4
			17				16
Spring Term			Credit	Spring Term			Credit
CSSE	132	Introduction to Computer Systems Design	4	CSSE	304	Programming Lang. Con	4
MA	113	Calculus III	5	CSSE	376	Software Quality Assurance	4
HSS		Elective	4	MA			
Science		Elective	4	RH	330	Elective	4
			17			Technical and Professional Communication	4
							16
Junior Year				Senior Year			
Fall Term			Credit	Fall Term			Credit
CSSE	371	Software Requirements Engineering	4	CSSE	477	Software Architecture	4
CSSE	372	Software Project Management	4	CSSE	497	Senior Project I	4
MA	381	Introduction to Probability with Statistical Applications	4	HSS		Elective	4
		Domain track course	4			Domain track course or free elective	4
			16				16
Winter Term			Credit	Winter Term			Credit
CSSE	332	Operating Systems	4	CSSE	498	Senior Project II	4
CSSE	374	Software Design	4	CSSE		Elective	4
HSS		Elective	4	HSS		Elective	4
		Domain track course	4	Free		Elective	4
			16				16
Spring Term			Credit	Spring Term			Credit
CSSE	373	Formal Methods in Specification and Design	4	CSSE	499	Senior Project III	4
CSSE	375	Software Construction and Evolution	4	HSS		Elective	4
HSS		Elective	4	Free		Elective	4
		Domain track course or free elective	4				12
			16	Total credits required: 192			

The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.

- 5. Four credits of science electives, which can be any CHEM, GEOL, PH, or AB courses not already required for the software engineering major.
- 6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
- 7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

- CSSE 120, Introduction to Software Development
- CSSE 220, Object-Oriented Software Development
- CSSE 230, Data Structures and Algorithm Analysis
- CSSE 371, Software Requirements Engineering
- CSSE 374, Software Design

Two additional courses in software engineering chosen from CSSE 372, 373, 375, and 477.



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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation-contact Air Force ROTC for more details.

Scholarships

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

Profession of Arms Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.

Communications Skills Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

General Military Courses

Freshman Year			Credit	Sophomore Year			Credit
AS 101	Found. of the US Air Force I	1		AS 201	Evol. of Air & Space Power I	2	
AS 101L	Leadership Laboratory	0		AS 201L	Leadership Laboratory	0	
AS 102	Found. of the US Air Force II	1		AS 202	Evol. of Air & Space Power II	2	
AS 102L	Leadership Laboratory	0		AS 202L	Leadership Laboratory	0	
AS 103	Found. of the US Air Force III	1		AS 203	Evol. of Air & Space Power III	2	
AS 103L	Leadership Laboratory	0		AS 203L	Leadership Laboratory	0	

Professional Officer Courses

Junior Year			Credit	Senior Year			Credit
AS 301	Air Force Lead. Studies I	4		AS 401	Nat.Sec.Aff./Prep. for Active Duty I	4	
AS 301L	Leadership Laboratory	0		AS 401L	Leadership Laboratory	0	
AS 302	Air Force Lead. StudiesII	4		AS 402	Nat.Sec.Aff./Prep. for Active Duty II	4	
AS 302L	Leadership Laboratory	0		AS 402L	Leadership Laboratory	0	
AS 303	Air Force Lead. Studies III	4		AS 403	Nat.Sec.Aff./Prep. for Active Duty III	4	
AS 303L	Leadership Laboratory	0		AS 403L	Leadership Laboratory	0	

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.



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quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art	Anthropology
English and Literature	Economics
Foreign Languages(German, Japanese, and Spanish)	Geography
History	Political Science
Music	Psychology
Philosophy and Religion	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- Global Studies (GS prefix): Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- Ideas and Arts (IA prefix): Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.
- Society and Values (SV prefix): Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communications are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communications is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general lower level courses (100 and 200 level) tend to be broad surveys of particular subject areas within disciplines. Upper level courses (300 and 400 level) are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General
 - All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)
2. Rhetoric and Composition
 - All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted free elective transfer credit, but are not exempted from RH 131.
 - EXEMPTION: An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. Any HSS course may be substituted for RH 131 for exempted students.
 1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.
 2. Has received grades of B or higher in all high school English courses.
3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. 4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. 5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.
 1. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.
 2. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three thematic categories as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each thematic category in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
 3. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
 4. Students may not earn foreign language credit in their native languages.
 5. Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. 6. Minors

- Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

HELP WITH REQUIREMENTS

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, or Spanish, by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

Minor	Advisor
Anthropology	Scott Clark
Art	Steve Letsinger
East Asian Studies	Huei-Ying Kuo
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter
Geography	Michael A. Kukral
History	Samuel Martland
Japanese	Maki Hirovani
Language and Literature	Caroline Carvill
Music	Gary Turner
Latin American Studies	Gustavo Garcia

Philosophy and Religion	Heinz Luegenbiehl
Political Science	Terrence Casey
Psychology	Patrick D. Brophy
Spanish	John Gardner

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Introduction to East Asian History 4R-OL-4C

Examine the changing political-economic and cultural orders in the East Asian region (including China, Japan, and Korea) from imperial to modern era.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Asian Religions and Philosophy 4R-OL-4C

Focuses on the thought systems of India, China, and Japan. Discusses Hinduism, Buddhism, Confucianism, Taoism, and Shinto.

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History 4R-OL-4C

Explores the history and interaction of major world regions, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction’s humanistic usefulness in examining human values from an “extra-species, extra-terrestrial” perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 285 Humans and Culture 4R-OL-4C

Examines human adaptation and diversity; language and its use; the development and variety of economic, political, religious, family gender and expressive institutions.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS330 Contemporary Global Film 3R-3L-4C.

Examines films outside of the Hollywood tradition with a consideration of the cultural, political, and economic

influences that shape film.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 350 International Trade and Globalization 4R-OL-4C Pre: SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Pre: SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Pre: SV 151

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 363 European Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of selected European political systems.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Contemporary Japan (Field trip to Japan) 4R-OL-4C

Examine contemporary Japan through the lectures, reading, and discussions during the course. Explorer the culture through the field trip to Japan.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 384 Japanese Society 4R-OL-4C

Examines the context within which individual Japanese live and work in contemporary Japanese society. Considers the "traditional" roots of Japan, the impact of industrialization, and current trends. Emphasizes the change and continuity in Japanese life, including the family and marriage, rural and urban lifestyles, education, and the organization of management and labor.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS425 Cities and Technology in the Industrial Age 4R-OL-4C

Explores development of cities and the machines and systems that make them possible as human life became more and more urban and industrial from 1700 to the present. Compares urban growth and city life in different parts of the world.

GS430 World Drama 4R-OL-4C

Examines drama from multiple cultures and time periods through a thematic lens.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS470 Japanese Media 4R-OL-4C

Explores historical and contemporary media-related Japanese culture, both in visual and text communications.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

IDEAS AND ARTS -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R-OL-4C

Introduces the student to the methods and subject matter of philosophy through a selective consideration of fundamental philosophical problems such as the nature of reality, the existence of God, the criteria of knowing, and the basis of morality.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Jane Austen and the Rhetoric of Fiction 4R-OL-4C

Provides a guide to reading, appreciating, and analyzing Jane Austen's major novels. Analyzes a variety of film adaptations, comparing them to the novels in their rhetorical effects.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 3R-3L-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Concepts 4R-OL-4C

Teaches basic techniques of music notation and analysis of melody, harmony, rhythm, form, and style. Includes a comprehensive Analysis Project.

IA 302 Philosophy of Religion 4R-OL-4C

Examines the basic philosophical problems found in religion. Deals specifically with the nature of religion, the nature and existence of God, religious language, and the religious life.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 330 Documentary Film 3R-3L-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA338 Medicine in Literature 4R-OL-4C

Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA340 Ethics in Human Communication 4R-OL-4C

Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 346 Music Theory II: Applications 4R-OL-4C Pre: IA246 or consent of instructor

Applies notational and analytical techniques to arranging/composing tasks, using music notation software.

IA 348 Music Performance 1R-0L-1R Pre: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C Pre: SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C Pre: SV 151

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Pre: SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes

behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C Pre: SV 151

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Pre: SV 151

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Pre: SV 151

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

IA 471 Literature of Madness 4R-OL-4C

Analyzes the literary, biographical, and scientific relationships between artistic and manic-depressed temperaments. Examines how "great wits and madness" relate.

SOCIETY AND VALUES -- Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 151 Principles of Economics 4R-OL-4C

Includes both microeconomics and macroeconomics. Analyzes market behavior. Considers production and pricing decisions under alternative industrial structures. Examines the determinants of economic growth, unemployment and inflation, including fiscal and monetary policy.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

Surveys learning, motivation, personality, intelligence, abnormal behavior, social behavior, perception, emotion, and psychobiology. Stresses objective analysis of behavior and provides a foundation for advanced courses.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 200 Career Preparation 1R-OL-1C W,S

This course is for economics majors, to be taken in the second or third year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resume preparation. Cross-listed with CHEM200, and MA200.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV 244 Music History: Medieval, Renaissance, Baroque 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 245 Music History: Classical, Romantic, Modern 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 272 Experimental Psychology 4R-OL-4C

Emphasizes experimental analysis of perception, motivation, learning, and personality. Programmed and independent experiments are performed. Laboratory periods are arranged.

SV 288 Introduction to Sociology 4R-OL-4C

Examine the social and historical construction of our personal identity based on race, class, and gender as well as how social and global inequality is associated with these categories.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R-OL-4C

Examines the ethical issues faced by professional engineers in the global corporate context. Deals with such topics as codes of ethics, professional autonomy, employer authority, and whistle blowing.

SV 304 Bioethics 4R-OL-4C

Introduces students to basic issues in bioethics such as physician-patient relationships, the conduct of research, cross-cultural concerns, and codes of ethics.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 350 Managerial Accounting 4R-OL-4C Pre: SV 151

Covers accounting concepts and procedures for preparation of financial reporting. Emphasizes use of accounting as a tool for management control and decision making.

SV 351 Managerial Economics 4R-OL-4C Pre: SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. In addition to SV 151, students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Pre: SV 151

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Pre: SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Pre: SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Pre: SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Pre: SV 151

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Pre: SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 373 Gender Issues4R-OL-4C

Examines male-female differences in behavior, personality, emotion, and cognition. Examines how men and women differ as they pursue the goals of life and the degree to which these differences are innate or learned.

SV 375 Personality Theories4R-OL-4C

Presents an organized summary of major contemporary theories of personality. Compares and contrasts theories of human behavior. Analyzes the degree that behavior is purposive, unconscious, instinctive, learned, modifiable, and predictable.

SV 382 Anthropology of Religion 4R-OL-4C

Examines various concepts and practices pertaining to the supernatural, focusing primarily on indigenous religions around the world. Discusses the relationships of religious beliefs, values, and practices with social organization, economic behavior, subsistence systems, and technology

SV 385 Archaeology & Prehistory 4R-OL-4C

Examines the human past through the analysis of cultural artifacts: the course focuses on the methods and techniques of archaeology and the study of the major cultural and social transformations from foraging to agricultural and complex civilizations.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and ongoing evolution: examines the evidence of the fossil record and genes, compares human behavior with other primates, considers physical basis for behaviors, and the extent and causes of human physical diversity..

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C Pre: SV 151

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

COMMUNICATION

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis of texts and images, research methods, and the conventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Pre: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

SPECIAL TOPICS AND DIRECTED STUDY

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX496 Seminar for HSS Senior Project 2R-OL-2C F Pre: Economics or International Studies major and Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX497 Directed Study for HSS Senior Project 2R-OL-2C Arranged Pre: XX496 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double

majors.

MODERN LANGUAGES

(NOTE: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Pre: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Pre: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Pre: GE 213

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Pre: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C

Summer Pre: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Pre: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-0L-4C S

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-XL-4C Summer

Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

HSS MAJORS

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning OutComes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 - A. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 - B. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 - C. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 - A. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 - B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 - A. Assemble and evaluate resources for research in international studies.
 - B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA233 World Literature

GS163International Relations

GS285Humans and Culture

GS291World Geography
SV151 Principles of Economics
GS223World History

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

- a. International Political Economy: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose at least three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General List

IA353 History of Economic Thought
GS322Industrial Revolution in a Global Context
GS350International Trade and Globalization
GS351International Finance
GS352Economic Growth and Development
GS361Politics of the Global Economy
SV328 Comparative Business History
SV354 Environmental Economics

Regional List

GS128Introduction to East Asia
GS161Comparative Politics
GS222Modern Latin American
GS366European Union
GS363European Politics and Government
GS399Geography of the Middle East
GS492Geography of Africa

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

- a. Comparative Cultures: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322Industrial Revolution in Global Context
GS333Travel in World Literature
GS334Global Novel in the 20th Century
GS432Literature of the Global Economy
GS462Postcolonial Literature
SV191 Cultural Geography
SV201 Religion and Ecology
SV226The West in the East
SV382Anthropology of Religion

Regional list (including but not limited to the following courses)

IA311 Topics in German Culture I
GS128Introduction to East Asia
GS207Asian Religions and Philosophy
GS222Modern Latin America
GS313Contemporary Spain
GS327Modern China
GS335Arabic Literature
GS379Japanese Culture

GS391Contemporary Europe
GS442Art History: Reniassance to Modern
GS492Geography of Africa

1. Individualized Major: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS MINORS

MINOR IN ANTHROPOLOGY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

1. Five Courses in Anthropology.
2. The following three courses are required:
 - o GS 285 Humans & Culture
 - o SV 385 Archaeology & Prehistory
 - o SV 386 Human Evolution
- A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- Substitutions may be made with the approval of the Minor Advisor

Courses

- o GS 384 Japanese Society
- o SV 382 Anthropology of Religion
- o XX 399 Special Topics
- o XX 499 Directed Study

MINOR IN ART

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

1. Five Courses in Art:
 - a. The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor

Courses

- o GS442 Art History: Renaissance to Modern
- o IA142 Drawing
- o IA148 Beginning Photography
- o IA244 Design and Color
- o SV242 Visual Arts in Civilization

MINOR IN EAST ASIAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS128 Introduction to East Asian History
 - GS207 Asian Religions and Philosophy
 - GS324 Gender and Work in China
 - GS327 Modern China
 - GS384 Japanese Society
 - SV226 The West in the East
 - SV326 Overseas Chinese
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN ECONOMICS

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Principles of Economics (SV 151);
 - b. Intermediate Microeconomics (IA 350) or Intermediate Macroeconomics (IA 351);
 - c. Three additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- GS350 International Trade and Globalization
- GS351 International Finance
- GS352 Economic Growth and Development
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- IA352 Game Theory
- IA353 History of Economic Thought
- IA450 Mathematical Economics
- IA453 The Entrepreneur
- SV151 Principles of Economics
- SV350 Managerial Accounting
- SV351 Managerial Economics
- SV352 Money and Banking
- SV353 Industrial Organization
- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX499 Directed Study

MINOR IN EUROPEAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS313 Contemporary Spain

- GS337 Shakespeare's Europe
 - GS363 European Politics and Government
 - GS366 The European Union
 - GS431 Literary London
 - GS469 Contemporary British Fiction and Film
 - GS491 Geography of Europe
 - IA311 Topics in German Culture I
 - IA337 European Romanticism
 - SV222 Western Civilization to 1500
 - SV223 Western Civilization from 1500 to the Present
 - SV291 Medieval Europe
 - SV413 Contemporary Germany
 - XX399 Special Topics
 - XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN GEOGRAPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS191 Geography of Middle East
- GS222 Modern Latin America
- GS291 World Geography
- GS327 Modern China
- GS391 Contemporary Europe
- GS491 Geography of Europe
- GS492 Geography of Africa
- SV191 Cultural Geography
- SV291 Medieval Europe
- XX399 Special Topics
- XX499 Directed Study

MINOR IN HISTORY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS128 Introduction to East Asian History
- GS221 Colonial Latin America
- GS223 World History
- GS222 Modern Latin America
- GS324 Gender and Work in China
- GS327 Modern China
- GS422 Industrial Revolution in Global Context
- IA388 Chinese Nationalism
- SV222 Western Civilization to 1500
- SV223 Western Civilization since 1500
- SV226 The West in the East
- SV322 Disasters and Modern Society since 1700

- SV326 Overseas Chinese
- SV328 Comparative Business History
- SV329 Cities in Latin American History
- XX399 Special Topics
- XX499 Directed Readings

MINOR IN LANGUAGE AND LITERATURE

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and HS330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS237 Science Fiction
- GS334 Travel in World Literature
- GS335 The Global Novel in the Twentieth Century
- GS336 Literature of War
- GS337 Shakespeare's Europe
- GS338 Contemporary Arabic Literature in Translation
- GS412 Topics in German Culture II
- GS431 Literary London
- GS432 Literature and Film of the Global Economy
- GS462 Postcolonial Literature
- GS469 Contemporary British Fiction and Film
- IA230 Fundamentals of Public Speaking
- IA231 Introduction to Poetry
- IA232 African American Music in American Literature
- IA233 World Literature
- IA234 Major American Writers
- IA236 Jane Austen and the Rhetoric of Fiction
- IA237 Introduction to Drama
- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature
- IA337 European Romanticism
- IA339 Rebellion in American Literature
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Masculinity and Work in Fiction and Film
- SV334 Utopian Thought and Literature
- SV336 Contemporary American Fiction
- SV337 20th century American Novel
- SV339 Literature and the Environment
- SV234 The American Dream
- XX399 Special Topics
- XX499 Directed Study

MINOR IN LATIN AMERICAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS221 Colonial Latin America
 - GS222 Modern Latin America
 - GS323 The Andean Countries of South America
 - GS313 Contemporary Spain
 - IA332 Don Quixote
 - SV329 Cities in Latin American History
 - SV338 Latin American Fiction: The Boom and Beyond
 - XX399 Special Topics
 - XX499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN MODERN LANGUAGES (GERMAN, JAPANESE, AND SPANISH)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture
IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation
Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413
Japanese Language and Culture X/XI/XII

XX 399 Special Topics
XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.
Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

MINOR IN MUSIC

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. A minimum of 40 credits must be earned to obtain the minor. 36 of these credits must be in HSS courses.
The remaining four (4) credits may be in an approved course from outside the HSS Department.
2. The following four courses are required:
 - SV244 Music History: Medieval, Renaissance, Baroque
 - SV245 Music History: Classical, Romantic, Modern
 - IA246 Music Theory I: Concepts
 - IA346 Music Theory II: Applications

To fulfill the fifth course requirement for the Area Minor in Music, the candidate may choose ONE of the following options:

- a. A course from outside the HSS Department, approved by the Minor Advisor, such as:
 - ECE481 Electronic Music Synthesis
 - PH404 Acoustics
 - PH460 Directed Study (music-related)
- b. IA 499: Directed Study in Music. Pre-requisite: consent of the Minor Advisor.
- c. A 348: Music Performance. Pre-requisite: consent of the Minor Advisor.
- d. Four (4) credits of Satisfactory participation in one or more of the formal Performing Groups (Concert Band, Jazz Ensemble, String Ensemble, and Chorus) are required. Performance credit may not be transferred from another college. One academic term of satisfactory participation earns one credit. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for "satisfactory participation" will be provided to the candidate by the Minor Advisor.

MINOR IN PHILOSOPHY AND RELIGION

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy and Religion has the following requirements:

1. Five courses in Philosophy and Religion, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS207 Asian Religions and Philosophy
- IA101 Introduction to Philosophy
- IA302 Philosophy of Religion
- IA335 Bible as Literature
- SV201 Religion and Ecology
- SV303 Business and Engineering Ethics
- SV304 Bioethics
- SV382 Anthropology of Religion
- XX399 Special Topics
- XX499 Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS161 Comparative Politics
- GS163 International Relations
- GS361 Politics of the Global Economy
- GS366 The European Union
- GS363 European Politics and Government
- SV166 American Politics and Government

- SV369 British Politics and Government
- SV463 Seminar on America's Future
- XX399 Special Topics
- XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Five courses in Psychology, distributed as follows:
 - Principles of Psychology (SV 171).
 - Experimental Psychology (SV 272).
 - Three other Psychology courses.
2. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Courses

- IA471 Literature of Madness
- SV171 Principles of Psychology
- SV272 Experimental Psychology
- SV375 Personality Theories
- SV373 Gender Issues
- XX399 Special Topics
- XX499 Directed Study

German Technical Translator's Certificate Program

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute's degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German (one IA, one SV, and RH330 Technical and Professional Communication).

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade

point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.

- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.

Summary	Credits
First Year German (GE 111, 112, and 113 or approved equivalent)	12
Second Year German (GE211, 212, 213 or approved equivalent)	12
Third Year German (GE311 Topics in German Culture I; GE312 Reading German Texts; and GE313 Advanced Grammar and Translation Methods)	12
Fourth Year German (GE411 Technical Translation; GE412 Topics in German Culture II; and GE413 Contemporary Germany)	12
One IA course (any)	4
One SV course (any)	4
RH330 (required for most majors)	4
TOTAL	60



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Community Members

Industry Partners
Trustees
Parents

Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Military

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

Curriculum

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College,

- | |
|------------------------|
| Applied Biology |
| Biochemistry |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)**
- Biochemistry & Molecular Biology (Second Major Only)**
- International Studies Major (IS) (Second Major Only)**
- Military**
- Pre-Professional Programs**

University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

Freshman Year

			<i>Credit</i>
MS	101	Leadership and Personal Development	1
MS	102	Introduction to Tactical Leadership	1
MS	103	Basic Tactical Leadership	1

Sophomore Year

			<i>Credit</i>
MS	201	Innovative Team Leadership	2
MS	202	Foundations of Tactical Leadership	2
MS	203	Foundations of Tactical Leadership II	2

Summer

			<i>Credit</i>
MS	206	ROTC Basic Camp	0

ADVANCED COURSE

Junior Year


			<i>Credit</i>
MS	301	Adaptive Team Leadership	4
MS	302		4
MS	303	Leadership Under Fire	4
		Leadership Under Fire II	4

Senior Year

			<i>Credit</i>
MS	401	Developing Adaptive Leaders	4
MS	402	Leadership in a Complex World	4
MS	403	Leadership in a Complex World II	4

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training.



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Parents

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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose- Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies (Air Force ROTC)

LT Col Adkins, MAJ Parks, CAPT Blystone

Aerospace Studies

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Pre: None
This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Pre: AS 101 or instructor permission
This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Pre: AS 102 or instructor permission
This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Pre: Enrollment in AS 101, AS 102, or AS 103
Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Pre: AS 103 or instructor permission
This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Pre: AS 201 or instructor permission
This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Pre: AS 202 or instructor permission
This course is a continuation of the winter quarter course designed to examine the general aspects of air and

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Pre: Enrollment in AS 201, AS 202, or AS 203

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Pre: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Pre: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Pre: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Pre: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Pre: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Pre: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Pre: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Pre: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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Course Descriptions

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Applied Biology & Biomedical Engineering

Applied Biology

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed AB110, AB120 or AB130 cannot receive credit for taking AB101.

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for AB or BE majors and not as an AB elective.

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed AB course.

The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for AB205 cannot earn credit for AB210 or AB230 without departmental consent.

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

Discusses the essential properties of eubacteria and archaea. Bacterial nutrition, growth, genetics and structural

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

AB 230 Eukaryotic Cell and Molecular Biology 3R-3L-4C S Pre: AB 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

AB 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111, or CHEM 105 or CHEM 201, or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

AB 310 Plant Structure & Function 3R-3L-4C S Pre: AB 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

AB 320 Ecology 3R-3L-4C F Pre: AB 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

AB 330 Evolutionary Biology 4R-0L-4C W Pre: AB 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

AB 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Pre: AB120, and Jr/Sr standing or consent of instructor

Designed to introduce applied biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

AB 399 Practice of Science 4R-0L-4C Pre: RH330 and MA223, or consent of instructor

This course focuses on skills required for implementing scientific research, including reading the primary literature, experimental design, scientific writing, oral presentations, research proposal writing, poster presentations, and investigation of research programs (through seminars or individual meetings). Each student chooses a project and research mentor by the end of the course.

AB 410 Infection and Immunity 4R-0L-4C Arranged Pre: AB 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

AB 411 Genetic Engineering 4R-0L-4C Arranged Pre: AB 205 or AB 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

AB 421 Applied Microbiology 4R-0L-4C Arranged Pre: AB110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

AB 431 Genomics and Proteomics 4R-0L-4C S Pre: AB 205 or AB210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

AB 441 Virology 3R-3L-4C Pre: AB110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

AB 451 Cancer Biology 4R-0L-4C Pre: AB 205 or AB210 or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

AB 461 Evolutionary Medicine 4R-0L-4C Arranged Pre: AB130, and AB205 or AB210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

AB 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged Pre: AB 205 or AB210 or consent of instructor

Strategies and methods used to identify and understand the genetic and molecular bases of inherited human disease are addressed. Topics include, human population genetics, pedigrees, genetic and physical mapping of human genes, linkage analysis, and diagnostic testing. Primary literature is routinely utilized.

AB 491 Special Topics in Applied Biology XR-0L-XC Arranged Pre: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed AB course.

AB 492 Directed Study in Applied Biology XR-XL-XC Arranged Pre: Consent of instructor

Covers applied biology material of mutual interest to the student and instructor which cannot be experienced in any other listed AB course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the ABBE department is required to use this course to fulfill AB elective credit requirements.

AB 496 Senior Thesis Research I 0R-6L-2C F, W, S Pre: AB 399 and consent of instructor

Initiation of senior thesis under the direction of an ABBE faculty mentor. Major tasks include creation and submission of a research proposal and piloting procedures. Additional requirements for adequate progress determined by each faculty mentor.

AB 497 Senior Thesis Research II 0R-12L-4C F, W, S Pre: AB 399 and consent of instructor

Continuation of research under the direction of an ABBE faculty mentor. Major tasks include data acquisition and methodological refinement. Additional requirements for adequate progress determined by each faculty mentor.

AB 498 Senior Thesis Research III 0R-12L-4C F, W, S Pre: AB 399 and consent of instructor

Continuation of research under the direction of an ABBE faculty mentor. Major tasks include data acquisition and preliminary analysis. Additional requirements for adequate progress determined by each faculty mentor.

AB 499 Senior Thesis Research IV 0R-6L-2C W Pre: AB 399 and consent of instructor

Completion of senior thesis under the direction of an ABBE faculty mentor. Major tasks include final analysis, public presentation of results, and submission of the written thesis. Additional requirements for adequate progress determined by each faculty mentor.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4CW Pre: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE201 Biomedical Measurements 3R-3L-4C Pre: BE100, ES203

Discuss the measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors (temperature, force, pressure, velocity, etc), and basics of PIC microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I: 3R-3L-4C W Pre: AB120, AB205

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Pre: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents

manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of cradle to cradle design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II: 3R-3L-4C S Pre: BE310

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3CC W Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE351 and BE361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Instrumentation and Signal Processing 3R-3L-4C F Pre: Pre: BE 201 and ES 203, or consent of instructor

Topics include Circuit analysis, frequency analysis, biomedical transducers, design of biomedical devices, and introduction to imaging techniques.

BE 350 Biocontrol Systems 4R-0L-4C Pre: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE351: Biomedical Engineering Lab 1R-3L-2C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331 and BE361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE352: Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE353: Biomaterials Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Pre: BE 201, Coreq: EM204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 400 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Pre: BE390

This course begins the year-long capstone design project and continues to investigate the process of design in

biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Pre: BE410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Pre: BE420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 482 Bioengineering Statistics 4R-0L-4C Pre: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Pre: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Pre: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F, W, S Pre: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing, 3R-3L-4C W Pre: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Human Physiology A 3R-3L-4C W Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Human Physiology B 3R-3L-4C S Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Pre: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Pre: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 535.

BE 539 Multiscale Biomechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541 Medical Imaging 4R-0L-4C Pre: JR/SR/GR standing and consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including computed tomography, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed.

BE 543 Neuroprosthetics 3R-3L-4C Pre: BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Pre: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Pre: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Pre: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials

(e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Pre: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 565 Experimental Methods in Tissue-Biomaterial Interactions 3R-3L-4C S Pre: BE 361, or consent of instructor

This course focuses on teaching students experimental methods used for investigations of tissue-biomaterial interactions. Topics include bioethics issues associated with experiments on cells, tissues, animals, and people; biosafety issues associated with cells/tissues from animals and humans; the design, critique, and statistical analysis of experiments. Students conduct hands-on investigations of cell-biomaterial interactions which require the use of common laboratory equipment, aseptic technique, mammalian cell culture, and current molecular methods to investigate cell viability, structure, and function.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Pre: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 F,W,S

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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Course Descriptions

Minors

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Advanced Placement

Graduate Studies

CATALOG HOME

Chemical Engineering

Professors Artigue, Coronell, Hariri, D. Henthorn, K. Henthorn, McClellan, Nolte, Sauer, and Serbezov.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Pre: None

An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 1R-0L-0C F Pre: sophomore standing in Chemical Engineering

Career choices in chemical engineering. Internships and co-ops. Resume preparation. Interview skills

CHE 201 Conservation Principles and Balances 4R-0L-4C F Pre: CHEM 113 or concurrent registration in CHEM 112, MA 113 or concurrent registration, and PH 111 or concurrent registration

An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in the analysis of non-reactive chemical engineering processes will be addressed. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Pre: CHE 201

The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances. Applications of the principles of conservation of mass and energy to reactive and transient systems will also be addressed.

CHE 300 Career Preparation II 0L-0C F Pre: Junior standing in Chemical Engineering

Career choices; preparation of resume; preparation for summer positions; preparation for graduate programs. 2-5 contact hours per quarter.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Pre: CHE 201

Physical properties of fluids, fluid statics, laminar and turbulent flow, boundary layer concept, flow past objects and flow through porous media. Design of pipe networks and pumps. High speed ideal gas flow. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Pre: CHE 202, MA211

First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F, W Pre: CHE 303, MA212

Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Pre: CHE 110, MA211, MA212 or concurrent enrollment

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Pre: CHEM 113

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Pre: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304

Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Pre: CHE 320, CHE 304

Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Pre: CHEM 360 and CHE 304

The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Pre: Senior Standing in Chemical Engineering

Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Pre: CHE 321, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Pre: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Pre: CHE 321

Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Pre: CHE 416, CHE 404

Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Pre: CHE 417 or consent of instructor

Completion of an open-ended design project that will include written and oral communication of intermediate

results and a final written report.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor. Cross-listed with EP 411, and ECE 419.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers. Cross-listed with CE 420, ECE 466, ME 420, and BE 400.

CHE 440 Process Control 4R-0L-4C W Pre: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of sensors, transmitters and control elements, stability criteria, and frequency response. Use of control design software is emphasized.

CHE 441 Polymer Engineering 4R-0L-4C F Pre: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 450 Air Pollution 4R-0L-4C F or W Pre: Junior or Senior standing

An introduction to air pollution and its control with special emphasis on the engineering aspects. Discussions of meteorology, health effects, sources and types of pollution, industrial control technology. Student projects. Cross-listed with CE561.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Pre: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Pre: CHE 303 or CHEM361 or ME201 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C F or S Pre: Junior or Senior standing

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, designs to prevent fires and explosions. Informal safety review.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F, W, S Pre: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

Undergraduate-Graduate Courses

CHE 502 Transport Phenomena I 4R-0L-4C Pre: CHE 321 or consent of instructor

Most of the course focuses on the derivation, simplification, and solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal, laminar flows in both steady and unsteady systems will be covered. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux both in solids and in laminar flows will also be covered. Boundary layer theory will be discussed. Turbulent flow theories may also be addressed.

CHE 503 Transport Phenomena II 4R-0L-4C

Energy Transport: multidimensional systems; macroscopic balances for nonisothermal systems. Mass Transport: fundamentals of ordinary diffusion, multicomponent diffusion, pressure and thermal diffusion, coupled heat and mass transfer, boundary layer analysis, turbulent transport, mass transfer coefficients, macroscopic balances.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with BE 516, ECE 516, EP 510, and ME 516.

CHE 512 Petrochemical Processes 4R-0L-4C W (proposed) Pre: CHE 321 or consent of instructor

Multicomponent separation of petroleum by flash vaporization. Processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas and other fossil fuels. Group projects and presentations on refinery and petrochemical processes. Material balances and economic evaluations of the processes.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 511, ME 519, and ECE 519.

CHE 521 Advanced Chemical Engineering Computation 4R-0L-4C

The application of advanced mathematics to chemical engineering problems. The topics include: the formulation of the partial differential equations of kinetics and heat, mass and momentum transfer problems; series solution techniques; transform solution techniques; vector formulation; numerical methods for systems of differential equations; optimization, including linear programming, combinatorial optimization, and stochastic optimization techniques.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: advanced control using cascade, feed forward, nonlinear, and adaptive control; multivariable systems including RGA analysis and decoupling; a major control system design and implementation project using a modern distributed control system.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: AB110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: AB110, CHE 321 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Advanced Placement

Graduate Studies

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Chemistry

Professors Adcock, Allison, Brandt, R. DeVasher, Erwin, Morris, Mottel, Mueller, Shearer, Tilstra, and Weatherman

CHEM 111 General Chemistry I 3R-3L-4C F,W,S Pre: None
Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 112 Chemistry Honors 4R-3L-5C F Pre: Advanced placement
An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-4C W,S Pre: CHEM 111
Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 115 General Chemistry III 3R-3L-4C W, S Pre: CHEM 113 or CHEM 112
Topics in this course include acid-base reactions, electrochemistry, and coordination chemistry.

CHEM 200 Career Preparation 1R-0L-1C W,S
This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with MA200, and SV200.

CHEM 225 Analytical Chemistry 3R-3L-4C F, S Pre: CHEM 115
This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 251 Organic Chemistry I 3R-0L-3C F Pre: CHEM 113 or CHEM 112, Coreq: CHEM251L
An introduction to the classification of organic compounds, their structural features, including stereochemistry, and concepts related to reaction mechanisms and synthetic methods.

CHEM 251L Organic Chemistry I Laboratory 0R-3L-1C F Pre: CHEM 113 or CHEM 112, Coreq: CHEM251
Organic Laboratory techniques are developed along with appropriate spectroscopic methods. Assessment is in part via practicums. Computational chemistry methods and green chemistry approaches are also introduced.

CHEM 252 Organic Chemistry II 3R-0L-3C W Pre: CHEM 251, CHEM 251L, Coreq: CHEM 252L
Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis, and an introduction to the methods used to determine structure, including IR and NMR spectroscopy and mass spectrometry.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

CHEM 252L Organic Chemistry II Laboratory 0R-3L-1C W Pre: CHEM 251, CHEM 251L, Coreq: CHEM 252

A continuation of CHEM251L where additional, more complicated synthetic techniques and methods along with additional spectroscopic techniques are introduced. Assessment is in part via practicums.

CHEM 253 Organic Chemistry III 3R-0L-3C S Pre: CHEM 252, CHEM 252L, Coreq: CHEM 253L

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 253L Organic Chemistry III Laboratory 0R-4L-1C S Pre: CHEM 252, CHEM 252L, Coreq: CHEM 253

Project based laboratory where techniques and skills developed in the previous organic laboratories are applied to more open-ended problems.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with AB264.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Pre: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Pre: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research under the direction of a member of the faculty selected by mutual agreement. Freshman and/or sophomore students may earn up to 2 credits and are required to submit a written report to the chemistry faculty.

CHEM 291 Introduction to Chemical Research 3R-3L-4C W Pre: CHEM 113 or CHEM 112

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members.

CHEM 304 Glassblowing 1R-3L-1C S Pre: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Pre: CHEM 225

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Pre: CHEM 225

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Pre: CHEM 252

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Pre: CHEM 330 and AB 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C

W, S Pre: CHE 303, CHE 304, and CHEM115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Pre: CHEM 115, MA 212 and MA 381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the

applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Pre: CHEM 111, MA 212, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 371 Environmental Analytical Chemistry (3R-4L-4C) F Pre: CHEM251 (or concurrent enrollment), and CHEM 225 and CHEM 264

This course is a laboratory-driven course where processes involved in performing environmental analytical chemistry are addressed. The focus of this course is on the chemical principles, analytical theory, instrumentation, and methods employed to quantitatively and qualitatively analyze pollutants in soil, water, biological tissues, and the atmosphere. Several techniques will be included in the course: sampling (obtaining a representative sample of complex system); sample preparation (extraction, clean-up, pre-concentration, derivitization, digestion, etc.); data acquisition (The laboratory will include use of EPA/ASTM methods/protocols, method development, etc.); and data handling and analysis (statistics, signals, noise, etc.).

CHEM 400 Chemical Communication I 1R-0L-1C W Pre: CHEM291

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. The emphasis of this course is to provide instruction in written communication. The fundamental skills useful for composition of professional chemistry communications is introduced culminating in a research prospectus. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 401 Chemical Communication II 1R-0L-1C F Pre: CHEM400 and CHEM490

Students will engage in both oral and written communication that will culminate in a professional seminar and a published thesis at the completion of this course sequence. Students will learn methods associated with constructing results and analysis sections of formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 402 Chemical Communication III 1R-0L-1C W Pre: CHEM 401

The emphasis of this course is to provide instruction in oral communication. Students will be taught fundamental skills useful for public presentation of research and its results. Students will also be required to attend the chemistry department's seminar series.

CHEM 403 Chemical Communication IV 1R-0L-1C S Pre: CHEM 402

Students will publish a thesis and deliver a professional seminar on their undergraduate research.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Pre: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 431 Biochemical Instrumentation 3R-4L-4C Pre: AB 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 433 Biochemistry Laboratory 0R-3L-1C S Pre: CHEM 330

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Pre: CHEM 252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Pre: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field

are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 445 Organometallic Chemistry 4R-0L-4C S Pre: CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 451 Organic Structure Determination 2R-8L-4C S Pre: CHEM 253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 452 Synthetic Organic Chemistry 4R-0L-4C F or W Pre: CHEM 253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 454 Theoretical Organic Chemistry 4R-0L-4C W Pre: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 455 Natural Products 4R-0L-4C Pre: CHEM 253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 457 Synthetic Polymer Chemistry 4R-0L-4C Pre: CHEM 252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 461 Advanced Physical Chemistry 4R-0L-4C Pre: CHEM 363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 462 Physical Polymer Chemistry 4R-0L-4C Pre: CHEM 361 or CHE 303

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Pre: CHEM 251 or CE 564 or consent of instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F, W, S Pre: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.

Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: Permission of instructor

Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Pre: CHEM291

Research under the direction of a member of the faculty selected by mutual agreement. Students may earn a maximum of 18 credits between CHEM 290 and CHEM 490. Students may register for 1 to 3 credits per quarter.



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Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Pre: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Pre: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE 400 Career Preparation Seminar 1R-0L-0C S Pre: CE 489

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 410 Senior Project 0R-8L-4C On Demand Pre: Senior class standing

Gives the student the opportunity to work on a civil engineering design or research project of the student's own choice, but which has met the approval of the staff prior to the start of the quarter. Requires presentation of oral and written reports. Not a regular elective offering.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Pre: CE 321

Matrix methods of structural analysis for two- and three- dimensional indeterminate structures. Force method, stiffness method, introduction to finite element analysis for civil engineers.

CE 424 Composite Material Mechanics 4R-0L-4C On Demand Pre: CE 321

Introduces various laminated composite materials such as reinforced plastics, laminated glass, plywood, laminated timber, and fiber-structural sandwich. Emphasis is on beam theory and plane stress analysis for such materials.

CE 430 Structural Design in Timber I 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of modern structures constructed of timber. Considers fasteners and their significance in design. Develops design criteria and their application to plane and three dimensional structures.

CE 431 Structural Design in Steel I 3R-0L-3C S Pre: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Pre: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 433 Structural Design in Steel II 4R-0L-4C On Demand Pre: CE 431

Covers the analysis and design of the various elements of a steel structure within the framework of the total structure. Includes composite design, plate girders, and multi-story building frames.

CE 434 Structural Design in Concrete II 3R-3L-4C Pre: CE 432

Advanced topics in reinforced concrete analysis and design such as strut-and-tie modeling, and strengthening with fiber reinforced polymers.

CE 435 Bridge Engineering 4R-0L-4C On Demand Pre: CE 321

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Includes methods and procedures for the analysis and design of bridge structures. Considers standards and procedures for inspections and ratings of bridges and methods to increase the load capacity of existing bridges. Includes field inspections.

CE 436 Foundation Engineering 4R-0L-4C S Pre: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Pre: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C F Pre: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 444 Pavement Design and Highway Construction 4R-0L-4C On Demand Pre: CE 320

Introduction to analysis and design of rigid and flexible pavement systems; subgrade, subbase, base and surfaces; specifications, material testing and construction methods for soil stabilization, flexible and rigid pavements; pavement evaluation, maintenance and reconstruction.

CE 445 Construction Methods and Equipment 4R-0L-4C F Pre: CE 201 and CE 336, Co: CE 442

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Pre: CE 431 & CE 432

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will also look at environmentally safe and renewable building materials, energy efficient construction techniques, indoor air quality and moisture problems, etc. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Pre: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Co: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 471 Water Resources Engineering 4R-0L-4C W Pre: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Transportation Planning 4R-0L-4C On Demand Pre: Junior class standing

Analyzes the transportation planning process. Stresses goals and approaches to solutions as related to the urban transportation problem. Includes a class project.

CE 481 Transportation Engineering 4R-0L-4C W Pre: Senior class standing

Study of transportation functions and transportation systems including land, air and marine modes; transportation system elements including travel way, vehicle, controls and terminals; emphasis on highway geometric design.

CE 482 Urban Planning 4R-0L-4C On Demand Pre: Junior class standing

Applies general principles of systems analysis and control to urban and regional planning. Covers human settlements, location theory, simulation, plan formulation, selection and implementation. Includes a class project.

CE 486 Civil Engineering Design & Synthesis I, F, 1 R-3L-2C Pre: RH 330, CE 460 Co-Req: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be initiated by small teams of students to implement principles used in planning, design, and synthesis. Learning objectives include contracting, concept development, concept feasibility, planning and scheduling design work, data collection for subsequent design.

CE 487x Technical System Design & Synthesis W, 2R-2L-2C Pre: CE486 Co-Req: CE 488

Technical system design of subdisciplinary elements of civil engineering projects submitted by corporate and governmental sponsors will be completed by individual team members to fulfill the needs of a team project initiated with CE486 and continuing in CE488. The "x" will be used to identify subdiscipline designation (c = general civil design, e= environmental, g = geotechnical, s = structural, t = transportation, w = water resources).

CE 488 Civil Engineering Design & Synthesis II, W, 1R-2L- 2C, winter Pre: CE486 Co-Req: CE 487

Project management by small teams for civil engineering projects submitted by corporate and governmental sponsors will continue. Learning objectives include coordinate of major design work in subdisciplines, progress reporting to the client, critical path model management to keep the project on schedule to fulfill the needs of a team project initiated with CE486 and continuing in CE487.

CE 489 Civil Engineering Design & Synthesis III, S, 1R-3L-2C Pre: CE 487, CE488

Civil engineering projects submitted by corporate and governmental sponsors will be completed. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. Learning objectives include construction planning and cost, final reporting, and public presentation of findings.

CE 490 Directed Studies F,W,S 1-4 C Arranged. Pre: Approval of department head, adviser, and course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

Undergraduate-Graduate Courses

CE 520 Plates and Shells 4R-0L-4C On Demand Pre: CE 421 and MA 212

Development of classical plate equation and boundary conditions; solution of problems in rectangular and polar coordinates. Development of membrane and bending theories for shells of revolutions; solution to domes and storage tanks.

CE 522 Advanced Finite Element Analysis 4R-0L-4C On Demand Pre: CE 421

Development of finite element methods for solving plane strain, plane stress and field problems. Utilizes readily available finite element computer programs. Requires additional development of user computer programs.

CE 523 Structural Dynamics 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of structures subjected to dynamic loads. Covers elastic and inelastic responses with applications to earthquake design, blast-resistant structures and bridge vibration.

CE 525 Buckling Strength of Structures 4R-0L-4C On Demand Pre: CE 321

Discusses the buckling phenomenon of prismatic bars subjected to combined axial and transverse loads. Considers elastic and inelastic instability. Includes buckling of beams, columns, curved bars, rings, plates, trusses and rigid frames.

CE 530 Structural Design in Timber II 4R-0L-4C On Demand Pre: CE 430

Presents the analysis and design of structures constructed of timber. Tapered beams, curved beams, box beams, stressed-skin panels, tapered columns, built-up columns, laminated arches, plate connected trusses, pole structures, diaphragms, shearwalls.

CE 531 Structural Design in Masonry 4R-0L-4C S Pre: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 533 Behavior of Metal Structures 4R-0L-4C On Demand Pre: CE 433

Discusses the behavior of metal connectors, members and structures. Studies the significance of this behavior in terms of design and the development of specifications. This course is closed to students who have successfully completed CE 433 Structural Design in Steel II.

CE 534 Behavior of Concrete Structures 4R-0L-4C On Demand Pre: CE 432

Studies the behavior of beams, slabs, and columns of reinforced concrete, prestressed concrete and composite construction from the standpoint of design and the development of specifications.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C On Demand Pre: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Pre: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 561 Air Pollution 4R-0L-4C W Pre: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Treatability Studies 2R-6L-4C On Demand Pre: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 563 Unit Operations in Environmental Engineering 4R-0L-4C F Pre: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Pre: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Pre: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Pre: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Pre: CE 471

Environmental planning and management strategies are examined using computer simulation models. Students will be introduced to some of the most widely used models in the fields of hydrology, hydraulics, and stormwater quality (nonpoint source pollution).

CE 568 Applied Contaminant Transport Modeling 4R-0L-4C On Demand Pre: CE 460 or consent of instructor

Environmental planning and management strategies are examined using computer simulation models. Emphasis is on pollutant transport in various media and emerging pollution issues. Students are introduced to some of the most widely used models in the field of environmental engineering. Students also develop at least one pollutant transport model using common software such as EXCEL, MATHCAD.

CE 569 Environmental Systems Optimization 4R-0L-4C Pre: Senior or Graduate class standing

Application of the principles of operations research to constrained optimization of environmental systems. Typical topics include strategies for non-linear searches, linear programming, dynamic programming, etc.

CE 570 Fluid Mechanics in Water Resources Engineering 4R-0L-4C On Demand Pre: CE 371

Presents steady and unsteady flow problems in open channels and pipes, problems dealing with laminar and turbulent boundary layers, and problems including diffusion and dispersion. There will be occasional laboratory work to demonstrate physical modeling in water resources engineering.

CE 573 Groundwater Analysis 4R-0L-4C Pre: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Pre: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Pre: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A

comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

College & Life Skills

CLSK 100 College and Life Skills 1R-OL-1C F Pre: None

This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

CLSK 121 College English 4R-OL-4C Pre: Consent of Instructor

Focuses on understanding the basic patterns and conventions of writing, enhancing reading skills and written comprehension, and improving verbal communication and oral comprehension. This course is intended for students for whom English is a second language.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science & Software Engineering

Professors Anderson, Bohner, Boutell, Chenoweth, Clifton, Defoe, Laxer, Lo, Mellor, Mohan, Mutchler, Shillingford, Srivastava, and Wollowski

CSSE 120 Introduction to Software Development 3R-3L-4C F, W, S

An introduction to procedural and object-oriented programming with an emphasis on problem solving. Students will solve problems by developing software in both an interpreted language (Python) and a compiled language (C). Problems may include visualizing scientific or commercial data, interfacing with external hardware such as robots, or solving numeric problems from a variety of engineering disciplines. Procedural programming concepts covered include data types, variables, control structures, arrays, and data I/O. Object-oriented programming concepts covered include object creation and use, object interaction, and the design of simple classes. Software engineering concepts covered include testing, incremental development, understanding requirements, and teamwork.

CSSE 132 Introduction to Computer Systems 3R-3L-4C F,S Pre: CSSE 120

Provides students with an understanding of system level issues and their impact on the design and use of computer systems. Examination of both hardware and software layers. Basic computation structures and digital logic. Representation of instructions, integers, floating point numbers and other data types. System requirements, such as resource management, security, communication and synchronization, and their hardware and/or software implementation. Exploration of multiprocessor and distributed systems. Course topics will be explored using a variety of hands-on assignments and projects.

CSSE 220 Object-Oriented Software Development 3R-3L-4C F,W,S Prerequisite: CSSE 120

Object-oriented programming concepts, including the use of inheritance, interfaces, polymorphism, abstract data types, and encapsulation to enable software reuse and assist in software maintenance. Recursion, GUIs and event handling. Use of common object-based data structures, including stacks, queues, lists, trees, sets, maps, and hash tables. Space/time efficiency analysis. Testing. Introduction to UML.

CSSE 221 Fundamentals of Software Development Honors 3R-3L-4C F Prerequisite: A score of 4 or 5 on the APCS A exam or permission of instructor

This course is intended for students who have sufficient programming experience to warrant placement in an accelerated course covering the topics from CSSE 120 and CSSE 220. This course will satisfy the prerequisite requirements for courses that have CSSE 220 as a prerequisite.

CSSE 230 Data Structures and Algorithm Analysis 3R-3L-4C W,S Prerequisites: CSSE 220 or CSSE 221 with a grade of C or better, and MA 112

This course reinforces and extends students' understanding of current practices of producing object-oriented software. Students extend their use of a disciplined design process to include formal analysis of space/time efficiency and formal proofs of correctness. Students gain a deeper understanding of concepts from CSSE 220, including implementations of abstract data types by linear and non-linear data structures. This course introduces the use of randomized algorithms. Students design and implement software individually, in small groups, and in a challenging multi-week team project.

CSSE 232 Computer Architecture I 3R-3L-4C F, W Prerequisites: CSSE 132, or CSSE 120 and ECE 130

Computer instruction set architecture and implementation. Specific topics include historical perspectives,

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic, ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control. Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prerequisite: CSSE 220 or CSSE 221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE290 Special Topics in Computer Science 1 - 4C Arr. Prerequisite: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prerequisite: CSSE230 and MA275

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arr Prerequisites: CSSE 220 or CSSE 221, and MA 212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W, S Prerequisites: CSSE 220 or CSSE 221, and CSSE 132 or CSSE 232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prerequisite: MA 275 and CSSE 230 (or concurrent enrollment in CSSE 230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prerequisites: CSSE 220 or CSSE 221, and MA 212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 371 Software Requirements Engineering 4R-0L-4C F Prerequisite: CSSE 230, RH 330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requisite: CSSE 371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict

management. Professional issues including career planning, lifelong learning, software engineering ethics, and the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prerequisite: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Design 4R-0L-4C W Prerequisite: CSSE 371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 4R-0L-4C S Prerequisite: CSSE 374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prerequisite: CSSE 230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prerequisite: CSSE 332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prerequisite: CSSE 304

A survey of some current and emerging programming languages, focusing on unique language paradigms—ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prerequisites: CSSE 232, CSSE 304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prerequisite: CSSE 230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prerequisite: CSSE 220 or CSSE 221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 433 Advanced Database Systems 4R-0L-4C S Prerequisite: CSSE 333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prerequisites: CSSE 332 and MA 275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and

integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prerequisite: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence 4R-0L-4C Arr Prerequisite: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prerequisites: CSSE 220 or CSSE 221, and MA 212 (MA 371 or MA 373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prerequisites: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prerequisites: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prerequisites: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 477 Software Architecture 4R-0L-4C F Pre: CSSE 374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 479 Cryptography 4R-0L-4C S Prerequisites: CSSE 220 or CSSE 221, and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prerequisite: CSSE 230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE487 Senior Research Project I 4C Arr Prerequisite: RH330 and senior standing

CSSE488 Senior Research Project II 4C Arr Prerequisite: CSSE487

CSSE489 Senior Research Project III 4C Arr Prerequisite: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arr Prerequisite: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arr Prerequisite: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arr Prerequisite: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arr Prerequisite: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arr Prerequisite: RH 330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arr Prerequisite: CSSE 494

CSSE 496 Senior Thesis III 4C Arr Prerequisite: CSSE 495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Project I 4C F Prerequisite: CSSE 371

CSSE 498 Senior Project II 4C W Prerequisite: CSSE 374 and CSSE 497

CSSE 499 Senior Project III 4C S Prerequisite: CSSE 498

Group software engineering project requiring completion of a software system for an approved client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure.



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About

Admissions

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Student Life

News

Calendars

Alumni

Athletics

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CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

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Electrical & Computer Engineering

Professors C. Berry, Black, Doering, Eccles, Grigg, Herniter, Hoover, Hudson, Moore, Mu, Padgett, Radu, Rostamkolai, Simoni, Song, Throne, P. Walter, Wheeler, and Yoder.

ECE 130 Introduction to Logic Design 4R-0L-4C F,W,S Pre: None

Combinational logic analysis and design, Boolean algebra, gate-level optimization, switch-level circuits, propagation delay, and standard combinational components. Sequential circuit analysis and design, flip-flops, timing diagrams, registers, counters, and finite state machine controllers. Design projects using circuit simulator and implementation in hardware.

ECE 160 Engineering Practice 0R-4L-2C F, W Pre: none

The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

ECE 203 DC Circuits 3R-3L-4C F, W, S Pre: MA111 and PH112

Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

ECE 204 AC Circuits 3R-3L-4C F, W, S Pre: ECE203 with a grade of C or better and PH113

Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Dynamical Systems 3R-3L-4C F, W, S Pre: ECE204 and MA211

Review of matrix and differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical and mechanical systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C W,S Pre: MA 211

A course designed for engineers (other than electrical or computer) covering analysis of passive circuits, introduction to op-amps, instrumentation, sinusoidal steady-state, a-c power, and induction motors. EE and CPE majors may not take this course.

ECE 207 Electrical Engineering 3R-3L-4C F,W Pre: ES 203

A course designed for engineers (other than electrical or computer) covering AC power, three-phase systems, magnetic circuits, transformers, machines, strain gauges, RTDs and thermocouples, noise and shielding, and feedback systems. Integral laboratory. EE or CPE majors may not take this course.

ECE 230 Introduction to Microcontrollers 3R-3L-4C F, W Pre: ECE130, CSSE120

Development of embedded systems with microcontrollers. Microcontroller architecture, instruction set,

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

programmer's model, hardware modules, and assembly language programming. Data representation and storage. Memory management. The C programming language, data structures and programming styles. Input and output devices. Data communications. Sensors and actuators. Real-time event measurement, generation and control. Interrupt generation and processing. Labs and a term project.

ECE 250 Electronic Device Modeling 3R-3L-4C F,W,S Pre: ECE 204, MA 211

Modeling, analysis, and simulation of electronic circuits that contain two-terminal and three-terminal semiconductor devices. Large-signal, biasing, and small-signal analysis models. Introduction to wave shaping circuits, switching circuits, and amplifiers. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Pre: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,S Pre: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Integral laboratory.

ECE 320 Linear Control Systems 3R-3L-4C W,S Pre: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C W,S Pre: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C F,S Pre: CSSE 232

Pipelining, memory hierarchy, peripherals, parallel processing, cost-performance tradeoffs, and a review of new topics in the areas of computer architecture or parallel processing. Computer use, memos, and discussion of current events.

ECE 333 Digital Systems 3R-3L-4C F,S Pre: ECE 130, ECE 205, ECE 250

Capabilities and limitations of digital CMOS logic devices. Design and evaluation of combinational and sequential logic circuits using Programmable Logic Devices. System integration with multiple components (FPGA, discrete components). CAD tools for design entry, timing simulation, and mapping to target devices. Troubleshooting using laboratory instrumentation. Laboratory notebooks. Informal reports. Integral laboratory.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Pre: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Pre: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,S Pre: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 343 High-Speed Digital Design 3R-3L-4C F,S Pre: ECE 300 and Computer Engineering Major

Signal path modeling through connecting lengths of transmission lines with lumped element models of discontinuities. Circuit parameters from geometries and material properties for resistance, capacitance, inductance and transmission line segments. Lossless and lossy transmission line circuit modeling. High-

frequency and high-speed behavior of passive components. Frequency spectrum of digital signals. Digital device driver and receiver modeling. Transmission line impedance discontinuity and termination techniques. Electric and magnetic field coupling mechanisms for capacitive and inductive crosstalk. Ground noise, power plane noise and resonance. Signal and power integrity issues in high-speed digital systems at both the printed-circuit board and chip levels.

ECE 351 Analog Electronics 3R-3L-4C W,S Pre: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal properties of op-amps. Integral laboratory.

ECE 362 Principles of Design 3R-0L-3C F, S

Pre for EE: ECE160, ECE250, ECE300, ECE340

Pre for CPE: ECE160, ECE250, ECE300

Pre for CS and SE majors: CSSE 374

Pre for ME majors: EM 103, ES 205, and ECE 207

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3R-1L-4C F, S Pre: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, and wind technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C W, S Pre: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C W,S Pre: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Pre: Consent of instructor

Special design or research projects.

ECE 410 Communication Networks 4R-0L-4C S Pre: Senior standing or consent of instructor

Layered architectures. Circuit and packet switching. ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Reliable message transport, internetworking.

ECE 412 Software Defined Radio 4R-0L-4C Pre: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front-end, and clock-jitter of the A/D. As a course project students will design and simulate a complete software-defined radio.

ECE 414 Wireless Systems 4R-0L-4C W Pre: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Pre: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with CHE 405, EP 410, and ME 416.

ECE 418 Fiber Optic Systems 4R-0L-4C S Pre: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing systems, and optical networks. Topics include basic architectures, component overview, system design, and expected degradations along with mitigation techniques. An oral presentation of a technical paper is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Pre: ECE 320 or ME 406

Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prerequisites: ECE 320 or ME 406, Programming proficiency

This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Pre: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Pre: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Pre: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, W Pre: ECE 362

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W, S

Pre for EE: ECE310, ECE320 ECE333, ECE341, ECE351, ECE370 or ECE371, ECE380, ECE460

Pre for CPE: CSSE332, ECE331, ECE332, ECE333, ECE342, ECE351, ECE380, ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W, S Pre: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Pre: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Pre: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Pre: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Pre: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/PH 437 Introduction to Image Processing 3R-3L-4C Pre: MA 212 and Junior standing

Basic techniques of image processing. Discrete and continuous two-dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory. Same as PH 437.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Pre: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Pre: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Pre: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Pre: Consent of instructor

Special design or research projects.

Undergraduate-Graduate Courses

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Pre: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Pre: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor

Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Cross-listed with ME 519, EP 511, and CHE 519.

ECE530 Advanced Microcomputers 3R-3L-4C S Pre: Graduate standing and ECE 331 or ECE 230; or ECE 331 or ECE 230 with a grade of B or better; or consent of instructor

32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design

using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software debugging tools. Integral laboratory.

ECE534 High-Speed Digital Design 4R-0L-4C W Pre: Graduate Standing, or ECE340 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal integrity issues in high-speed digital systems at printed-circuit board (PCB) and chassis levels. Frequency spectrum of digital signals. Frequency behaviors of passive components. Behavior models of drivers and receivers. Transient behaviors of transmission lines. Time-domain reflectometry. Signal reflection and ringing on printed-circuit board. Impedance discontinuity and matching. Load termination techniques. Capacitive and inductive crosstalk. Ground noise. Power plane noise and resonance. High-speed PCB design guidelines. PCB simulation tools.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Pre: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of instructor

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C W Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Wave-guide structures, scattering parameters, passive components, active components, computer-aided design of amplifiers, oscillators and mixers, microwave/millimeter-wave systems, microwave and millimeter-wave integrated circuits.

ECE542 Advanced Electromagnetics 4R-0L-4C F Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, power and energy, material properties, waves, reflections, radiation, EM field theorems, boundary value problems, skin effect.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Pre: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C S Pre: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C S Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Instrumentation amplifiers. A/D and D/A converters. Shock protection. Generation, recording and analysis of biological potentials (ECG, EMG, EEG). Ultrasound techniques and instrumentation. X-ray CAT techniques. Project involving the design of a significant instrument will run throughout

the course. No laboratory, but emphasis on computer simulation of the circuits studied.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C S Pre: Graduate standing and ECE 351; or ECE 351 with a grade of B or better; or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE 557 Analog Test and Product Engineering 3R-3L-4C F Pre: Graduate standing and ECE 300 and ECE 351; or ECE 300 and ECE351 with grades of B or better in both courses; or consent of instructor

Fundamental skills necessary to be an industrial integrated circuit test engineer or product engineer. Includes the economics associated with testing, impact of fabrication variation on devices, instrumentation associated with industrial testing, turning a data sheet into a test plan, industrial testing techniques for analog circuits, trade-offs between test time and test accuracy, statistical analysis of the data and statistical process control, the use of device interface boards necessary to control device loading for different tests. Integral labs with an industrial grade automatic tester (ATE).

ECE580 Digital Signal Processing 4R-0L-4C W Pre: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Pre: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE 582/PH 537 Advanced Image Processing 3R-3L-4C Pre: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as PH 537.

ECE 583 Pattern Recognition 3R-3L-4C S Pre: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 597 Special Topics in Electrical Engineering 4C Pre: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C arranged

Thesis topic selected in consultation with adviser. Graduate students only.



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Engineering Management

Professors Downing, Kline, Schumacher and Stamper

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4C

Pre: Junior, Senior, or consent of instructor

Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC

Pre: MG 461 or consent of instructor

Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC

Pre: MG 462 or consent of instructor

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C, Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT511 Graduate Seminar I 1R-0L-1C F

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT512 Graduate Seminar II 1R-0L-1C W

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT513 Graduate Seminar III 1R-0L-1C S

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT514 Graduate Seminar IV 1R-0L-1C Summer

Selected topics relevant to Engineering management are discussed by graduate students, faculty, and guest speakers.

EMGT520 Accounting for Technical Managers 4R-0L-4C - Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C, Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership, Change and Organizational Culture 4R-0L-4C - Management

Review of fundamental activities (planning, organizing, leading, controlling) related to the management of organizations. The concepts and techniques for maximizing the effectiveness of human resources in the achievement of organizational and project goals are emphasized. Topics include communication, team process, motivation, selection, development, and appraisal. Special focus is given to the management of human resources in a technical environment.

EMGT523 Marketing in New Product Development 4R-0L-4C, - Management

A study and overview of the components of marketing principles and how those mesh with management in a technical environment. Topics will include activities associated with product, price, promotion, and distribution and how these impact the technical manager from idea generation through delivery to and service for the customer.

EMGT524 Production/Operations Management 4R-0L-4C, Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-0L-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-0L-4C

This course introduces the concepts of innovation types (radical, incremental, disruptive) and patterns of

technology evolution. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy use, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, expert judgment (Delphi), road-mapping and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-0L-4C - Technical or Management

Addresses the major issues and techniques of project management, including team building, project evaluation and selection, scheduling techniques, quality management, development of negotiation and conflict management skills. Also examines project management success factors. Uses a large scenario planning exercise and several case studies to illustrate course content. Can be used as part of the technical or management core.

EMGT531 Economics for Technical Managers 4R-0L-4C - Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C - Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C - Management

The core of this course is the presentation of the Constructivist theory of communication and its application. Students are exposed to ethnographic interview methods and the concept of culture shock using the BAFA role-play simulation. Discussion of organizational culture includes a review of publications on this topic, the impact of culture on organizations, as well as strategies for change. May be used as a management core class.

EMGT534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing Technical or Management

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-OL-4C, Management

Reviews the strategy literature and the issues surrounding strategy implementation in the context of organizational change. Includes a team project that explores the strategic implications of globalization for specific industries during the next 10 years and the construction of scenarios as a tool for understanding and communication. Individual students will develop and evaluate strategy for a specific organization within the scenarios developed in the team project.

EMGT540 Fundamentals of Engineering Management 4R-OL-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT 551 Intellectual Property for Engineers and Scientists 4R-OL-4C Technical or Management Elective

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-OL-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C, Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization. Cross-listed with EMGT 486.

EMGT587 Systems Engineering 4R-0L-4C, Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C - Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Pre: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and

other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.



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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

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Engineering Mechanics

All courses in the engineering mechanics area are the responsibility of the Civil and Mechanical Engineering Departments.

EM 101 Statics 2R-0L-2C F Pre: None

Covers static force analysis. Introduces scalars and vectors with applications to the study of forces, moments, and couples. Stresses free body diagrams with engineering examples.

EM 103 Introduction to Design 1R-2L-2C S Pre: None

Introduces the engineering design process including problem definition, analysis, alternate solutions, specifications of final solution, and techniques of oral and written communications. Stresses the importance of teamwork through group design efforts.

EM 104 Graphical Communications 1R-2L-2C F Pre: None

Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication.

EM 120 Engineering Statics 4R-0L-4C F,S Pre: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, shear and bending moment diagrams, friction, and area moments of inertia. Emphasizes free-body diagrams.

EM 121 Statics and Mechanics of Materials I 4R-0L-4C F,S Pre: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, and strength and elastic deflection of engineering materials due to loads applied axially. Emphasizes free-body diagrams.

EM 202 Dynamics 4R-0L-4C F Pre: MA 112 and EM 120 or PH 111

Kinematics and kinetics of particles in space and rigid bodies in plane motion. Applications of the principles of Newton's laws, work-energy, impulse-momentum, and conservation laws to solutions of simple two-dimensional dynamics problems.

EM 203 Mechanics of Materials 4R-0L-4C F,W Pre: EM 120

Strength and elastic deflection of engineering materials due to loads applied axially, in torsion, in bending, and in shear. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 204 Statics and Mechanics of Materials II 4R-0L-4C F,S Pre: EM 121

Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 301 Fluid Mechanics 4R-0L-4C S Pre: EM 202

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

*EM403 Advanced Mechanics of Materials 4R-0L-4C S Pre: EM 203 or EM 204

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

EM 406 Vibration Analysis 4R-0L-4C F Pre: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

Undergraduate-Graduate Courses

***EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Pre: ME401 or consent of instructor**

Course may be repeated for different topics in fluid mechanics.

***EM 502 Advanced Dynamics 4R-0L-4C Pre: ES 205**

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

***EM 503 Advanced Vibration Analysis 4R-0L-4C W Pre: EM 406**

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.


***EM 505 Theory of Elasticity 4R-0L-4C Pre: EM 203 or EM 204**

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

***EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Pre: EM 403 and MA 330**

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.

*May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors: Bunch, Ditteon, Duree, Granieri, Joenathan, Kirkpatrick, Kirtley, Lepkowicz, Letfullin, McInerney, Moloney, Siahmakoun, Syed, Wagner, and Western.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W Pre: PH113
Scaling laws in small systems, basics of quantum mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, nanomechanics, cantilever oscillation, atomic-force microscope (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors.

EP 290 Directed Study Credit arranged Pre: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S Pre: EP280
Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, nanoscale heat: conduction, convection, and radiation. Nanophotonics in metals and semiconductors, surface Plasmon resonance and applications, photonic bandgap crystals, basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise. Cross-listed with EP 506.

EP 408 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor
Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing
Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Pre: EP 410 or equivalent course
Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-listed with ECE 419, and CHE 419.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

EP 415 Engineering Physics Projects I 4C S Pre: RH 330 and consent of the instructor

Team-oriented and/or independent design project work on selected topics in any engineering discipline but related to concepts to strengthen both the application and physics and engineering, design of project, building of prototype, experiments to test components and systems, and market analysis. Cross-listed with OE 415.

EP 416 Engineering Physics Projects II 4C F Pre: Consent of the instructor

Follow up course to EP415. To be taken as a sequence from the same department where EP415 was taken. Cross-listed with OE 416.

EP 417 Engineering Physics Projects III 2R-6L-4C W Pre: Consent of the instructor

Follow up course to EP416. To be taken as a sequence from the same department where EP415 and EP416 were taken. Cross-listed with OE 417.

EP 470 Special Topics in Engineering Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 406.

EP 508 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Pre: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Geology

GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Pre: CHEM 111 or CHEM 105

Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

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Mathematics

Mechanical Engineering

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Optical Engineering

Physics

Robotics

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MA 200 Career Preparation 1R-0L-1C W,S

This course is for mathematics and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200, and SV200.

MA 211 Differential Equations 4R-0L-4C F, W, S Pre: MA 113

First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F, W, S Pre: MA 113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F, W, S Pre: MA 112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Pre: MA 112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Pre: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arr Pre: CSSE 220 or CSSE221, and MA 212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W, (odd years) Pre: MA 113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F Pre: MA 113

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F Pre: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C S Pre: MA 211, MA 212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Pre: MA 211, MA 212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA 342 Computational Modeling 4R-0L-4C S Pre: MA 212 and one of CHE 310,CE 310,MA 332 or ME 323

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 348 Continuous Optimization 4R-0L-4C S (even years) Pre: MA 212

Optimization of nonlinear functions of real variables: algorithms for univariate optimization; Golden section, parabolic interpolation, hybrid methods; Newton's Method and variations for multivariate functions; conjugate gradients and quasi-Newton methods; line search strategies; penalty functions for constrained optimization; modeling and applications of optimization.

MA 351-6 Problem Solving Seminar 1R-0L-1C F, W, S Pre: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Pre: MA 275 and MA 113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Pre: MA 212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Pre: MA 212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Pre: MA 212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Pre: MA 275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Pre: MA 275

An introduction to modern abstract algebra and algebraic structures. Topics include congruence and modular

arithmetic; rings, ideals, and quotient rings; fields, finite fields, and subfields; groups and subgroups; homomorphisms and isomorphisms. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Pre: consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F, W, S Pre: MA 113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C (F) Pre: MA 381

This is an introductory course in statistical data analysis and mathematical statistics.

Topics covered include descriptive statistics, Sampling distributions (including the central Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Pre: MA 223 or MA 382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Pre: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary.

MA 386 Statistical Programming 4R-0L-4C Pre: previous programming course and either MA 223 or MA 382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Pre: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 390 Topics in the Mathematics of Engineering 1-2C (arranged) Pre:consent of instructor

A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

MA 421 Tensor Calculus and Riemannian Geometry 4R-0L-4C (arranged) Pre: MA 330

An introduction to the calculus of tensor fields and the local geometry of manifolds. Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

MA 423 Topics in Geometry 4R-0L-4C (arranged) Pre: MA371 or MA373 or consent of instructor

An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C (arranged) Pre: instructor permission

A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C (arranged) Pre: MA 330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to "direct methods." Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Pre: MA 212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C (arranged) Pre: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 435 Finite Difference Methods 4R-0L-4C W Pre: MA 332 or MA 371 or MA 373 or MA 433

An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Pre: MA 330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green's function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Pre: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Pre: MA 212 and one of MA 371 or MA 373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development "from the ground up."

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Pre: MA 223 or MA 381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Pre: MA 375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F, W, S Pre: consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based

on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C (arranged) Pre: MA 366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view.

Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C (arranged) Pre: MA 366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Pre: MA 371 or MA 373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Pre: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Pre: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C (arranged) Pre: MA 375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Pre: MA 375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Pre: MA 375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C (arranged) Pre: MA 378 or MA 375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Pre: CSSE 220 and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C (arranged) Pre: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Pre: MA 382, or MA 381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Pre: MA 223 or MA 382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Pre: MA 212 and either MA 223 or MA 382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Pre: MA 223 or MA 382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics, variable credit, Pre: consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Pre: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Pre: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F, W Pre: MA 492 or permission of the instructor

MA 494 Senior Project III 2C W, S Pre: MA 493

Participation in sponsored projects or problems with a substantial mathematical and/or computational content. Students typically work in teams of at most 3, with appropriate faculty supervision. Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of Senior Project must be completed in a form acceptable to the sponsor and the advisor.

MA 495 Research Project in Mathematics, variable credit, Pre: consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Pre: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Pre: MA 496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Pre: MA 497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C (arranged) Pre: MA 381


Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C (arranged) Pre: MA 223 or MA 381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Pre: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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Sophomore Engineering

working, casting, welding, heat treating and machining. Emphasizes the importance of considering manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Pre: ECE 207, ES 205, MA 223

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Computer Applications II 1R-3L-2C W,S Pre: ME 123, or CSSE 120, MA 212

Introduction to structured programming and applied numerical methods in scientific computing. The course uses applied problems in engineering and mathematics to introduce numerical methods such as numerical interpolation, finite differencing, integration, root finding, and linear algebraic system solutions. Matlab is taught as a vehicle for solving the problems numerically in a structured high speed environment.

ME 328 Materials Engineering 4R-0L-4C W Pre: CHEM 111

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Pre: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

***ME 401 Foundations of Fluid Mechanics 3R-3L-4C Pre: ES 202 or EM 301, MA 212**

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective*

***ME 402 Advanced Heat Transfer 4R-0L-4C Pre: ME 302**

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 403 Kinematics of Machinery 4R-0L-4C Pre: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

***ME 405 Theoretical Aerodynamics 4R-0L-4C F Pre: ES 202**

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 406 Control Systems 3R-3L-4C F Pre: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Pre: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of

the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are taken when available.

ME 408 Renewable Energy 4R-0L-4C Pre: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C F Pre: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Pre: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Pre: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Pre: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 410, ECE 416, and CHE 405.

***ME 417 Advanced Materials Engineering 4R-0L-4C Pre: ME 328 and EM 203 or EM 204**

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ECE 466, CHE 420, and CE 420.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Pre: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

***ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Pre: EM204**

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Pre: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix

composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Pre: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Pre: ES 205 or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

***ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Pre: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 430 Mechatronic Systems 3R-3L-4C F,W Pre: (ME 323 or CSSE 220 or ECE 230) and (ECE 207 or ECE 204) or consent of instructor

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

***ME 435 Robotics Engineering 3R-3L-4C S Pre: ME 430 and Senior class standing**

Interdisciplinary course in engineering systems applied to computer controlled automata. Topics include kinematics, control, operation, sensing, and design as applied to various types of industrial and other robots and programmable manipulators. A related project is required.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 450 Combustion 4R-0L-4C Pre: ME 301**

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises.

**May be used to satisfy Mechanical Engineering requirement for an advaced technical elective.*

ME 461 Aircraft Design 4R-0L-4C W Pre: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams.

ME 462 Thermal Design 4R-0L-4C W,S Pre: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Engineering Design Processes and Methodology 2R-3L-3C F,S Pre: 3rd qtr junior standing

Design of multi-component systems with consideration of societal and economic factors. Useful design techniques (such as modeling, CPM, optimization, probabilistic approaches, etc.) and factors influencing design (such as human factors, products liability, ethics, safety, etc.) are presented and discussed. Laboratory assignments emphasize case studies. (Students completing ME470 may not receive credit for EMGT 461.)

ME 471 Capstone Design I 1R-6L-3C W Pre: ME 470, ME 480

Design projects with industry. Students work in teams with three or four members on design projects furnished from external clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in oral presentations and Interim Written Reports which are submitted to the clients.

ME 472 Capstone Design II 1R-6L-3C S Pre: ME 471

This course is a continuation of ME 471. The student teams continue their design solutions to a general problem furnished by an external client. Continuous and regular communication with the outside clients is expected, as well as with the faculty advisors. During these ten weeks the teams continue refining their solutions, complete the detail design, make oral presentations of the final design, and complete and submit the Final Written Report.

ME 480 Machine Component Design 4R-0L-4C S & F Pre: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor

Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Senior class standing

Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged

Topics of current interests in mechanical engineering.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

***ME 501 Advanced Thermodynamics 4R-0L-4C F Pre: ME 301 or equivalent**

Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Pre: ME 302**

Course may be repeated for different heat transfer topics.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 503 Viscous Fluid Flow 4R-0L-4C Pre: ME 401**

Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Pre: ES 205, MA 212**

Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 506 Advanced Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**

Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 507 Applied Nonlinear Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**

Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liapunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 510 Gas Dynamics 4R-0L-4C F Pre: ES 202**

Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..*

***ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Pre: ES 205 and ME 323**

Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 512 Light Weight Structures 4R-0L-4C S Pre: MA 212 and EM 203 or EM 204**

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 513 Environmental Noise 4R-0L-4C F Pre: Senior class standing**

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

***ME 518 Advanced Kinematics 4R-0L-4C S Pre: ME 403**

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Cross-listed with ECE 519, EP 511, and CHE 519.

***ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Pre: EM 104 and Senior class standing**

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 522 Advanced Finite Element Analysis 4R-1L-4C S Pre: ME 422**

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 526 Turbomachinery 4R-0L-4C Pre: ES 205 or equivalent, or permission of instructor

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency. Students enrolled in ME 526 must complete a design project including complexities not covered in ME 426. Students may not receive credit for both ME 426 and ME 526

***ME 527 Computational Fluid Dynamics 3R-3L-4C Pre: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution. Students enrolled in ME527 must complete a design project not covered in ME 427. Students may not receive credit for both ME 427 and ME 527.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 536 Computational Intelligence in Control Engineering 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**

Machine learning and adaptation applied to feedback control, guidance and navigation. Neural Networks for pattern recognition, modeling and control. Radial basis function model identification by recursive least squares. Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.
**May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 550 Combustion 4R-0L-4C Pre: ME 301**

Study of the thermodynamics and kinetics of combustion processes and the underlying chemical processes. Topics covered include deflagration and detonation waves, combustion of solid, liquid, and gaseous fuels, and environmental impacts of compustion. Laboratory experience via in-class, hands-on exercises. Students enrolled in ME 550 must complete a design project not covered in ME 450. Students may not receive credit for both ME 450 and ME 550
**May be used to satisfy Mechanical Engineering requirement for an advaced technical elective.*

***ME 590 Thesis Research F,W,S**

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.
** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

***ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S**

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..*



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MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Pre: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Leaders' Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Leaders' Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

Junior Year - Advanced Course

MS 301: Adaptive Team Leadership 3R-3L-4C F Pre: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 challenges cadets to study, practice, and evaluate adaptive leadership skills as they are presented with challenging scenarios related to squad tactical operations. Cadets receive systematic and specific feedback on their leadership attributes and actions. Based on such feedback, as well as their own self-evaluations, cadets continue to develop their leadership and critical thinking abilities. The focus is developing cadets' tactical leadership abilities to enable them to succeed at ROTC's summer Leadership Development and Assessment Course (LDAC).

MS 302: Leadership Under Fire 3R-3L-4C W Pre: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when under fire are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Leader Development and Assessment Course (LDAC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Pre: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for LDAC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

**Overview of LDAC: Leader Development and Assessment Course
Summer Term Only**

LDAC/Warrior Forge is the crucible of the Army ROTC Program. As such, Cadet Command must provide the best professional training and evaluation possible for all cadets. The primary focus at LDAC is to evaluate each cadet's officer potential in a collective environment. The secondary purpose of LDAC is to validate specific skills taught on campus and to impart selective individual and collective common skills. LDAC represents the only opportunity for this command to assemble cadets from disparate schools into an environment with common operational conditions.

Senior Year - Advanced Course

MS 401: Developing Adaptive Leaders 3R-3L-4C F Pre: MS 303

MS 401 develops cadet proficiency in planning, executing, and assessing complex operations, functioning as a member of a staff, and providing performance feedback to subordinates. Cadets assess risk, make ethical decisions, and lead fellow ROTC cadets. Lessons on military justice and personnel processes prepare cadets to make the transition to Army officers. Cadets analyze, evaluate, and instruct cadets at lower levels. Both their classroom and battalion leadership experiences are designed to prepare cadets for their first unit of assignment.

They identify responsibilities of key staff, coordinate staff roles, and use situational opportunities to teach, train, and develop subordinates.

MS 402: Leadership in a Complex World 3R-3L-4C W Pre: MS 401

MS 402 explores the dynamics of leading in the complex situations of current military operations in the COE. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. They also explore aspects of interacting with nongovernmental organizations, civilians on the battlefield, and host nation support. The course places significant emphasis on preparing cadets for their first unit of assignment. It uses case studies, scenarios, and What Now, Lieutenant? exercises to prepare cadets to face the complex ethical and practical demands of leading as commissioned officers in the United States Army.

MS 403: Leadership in a Complex World II 3R-3L-4C S Pre: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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About

Admissions

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Student Life

News

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Alumni

Athletics

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Pre: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems.

OE 395 Optical Instrumentation 3R-3L-4C Arranged Pre: OE 280 and PH 292

Radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; signal conditioning and noise; CCD arrays; optical instruments; color; selected experiments on the application of optical instruments.

OE415 Optical Engineering Design I 2R-6L-4C S Pre: OE 295 Coreq: RH330 or consent of the instructor

Principles of design. Codes of ethics appropriate to optical engineers. Case studies related to optical engineering professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415. OE416 Optical Engineering Design II 2R-6L-4C F Pre: OE 415

Design project using formal design process; system-level design. Students work in teams to complete the first phase of the design. Teams translate customer needs to design specifications. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE417 Optical Engineering Design III 2R-6L-4C W Pre: OE416

Continuation of OE416 design project. Delivery of a functional prototype product. Complete product development documentation including a technical report, design documents, product design specification, drawings, acceptance test document, project plan. Oral presentation. Cross-listed with EP 417.

OE 435 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 435.

OE 450 Laser Systems and Applications 3R-3L-4C S Pre: PH 292 and MA 212 or JR standing or consent of instructor

Laser safety; Gaussian beam propagation; beam quality; optical resonators; longitudinal and transverse modes; stability, stimulated emission; population inversion; rate equations; gain and threshold; Q-switching and mode-locking; types of laser systems; laser applications.

OE 470 Special Topics in Optical Engineering 2-4 Credits Pre: Consent of instructor

Lectures on special topics in optics.

OE 480 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 Coreq: OE 360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Glass selection and introduction to computer-aided design. Classical lens design and design of imaging /non-imaging systems. Cross-listed with OE 580.

OE 485 Electro-Optics and Applications 3R-3L-4C W Pre: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Cross-listed with OE 595.

OE 490 Directed Research Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3R-3L-4C F Pre: OE393, ECE310 or graduate standing or consent of the instructor

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Soliton propagation. Relevant laboratories

OE 495 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-

Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); Review of interference and coherence; fringe visibility; third order aberrations; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Cross-listed with 595.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Pre: OE 295, PH 292, PH 316 or SR/GR standing or consent of instructor

Classical optics; exact ray tracing; aberrations, interference, polarization, spatial and temporal coherence; lasers and Gaussian beam propagation; diffraction; optical sources and detectors; selected applications of optics.

OE 535 Biomedical Optics 3.5R-1.5L-4C Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with BE 535.

OE 570 Special Topics in Optics 2 or 4C F,W,S Pre: OE 295, PH 292, and PH 316

Lectures on special topics in optics such as: optical materials, optics of thin films and infrared optics.

OE 580 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 Coreq: OE360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Glass selection and introduction to computer-aided design. Classical lens design and design of imaging/ non-imaging systems. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 480.

OE 585 Electro-Optics and Applications 3R-3L-4C W Pre: PH 292 and

PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, acousto-optic effect and modulators and scanners; non-linear effects; second-harmonic generation and frequency doubling. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 485.

OE 592 Fourier Optics and Applications 3R-3L-4C F Pre: SR/GR standing or consent of instructor

Two-dimensional linear systems; diffraction theory (Fresnel & Fraunhofer); imaging properties of lenses; frequency analysis of optical imaging systems; spatial filtering; optical information processing; Vander-Lugt filters; wavefront reconstruction; holography; optical computing.

OE 593 Fundamentals of Optical Fiber Communications 3R-3L-4CS

Pre: OE393 or graduate standing or consent of the instructor

Evolution of fiber optics links and networks: information rate, evaluation of fiber optic systems, optical fiber transmission link. Digital transmission systems: point-to-point links, line coding, error correction. Analog systems: links, dynamic range, noise figure, bandwidth, carrier-to-noise, multi-channel transmission, cross talk. WDM concepts: operational principles, passive components, system considerations. Optical networks: network topologies, performance of linear bus, performance of star architecture, SONET, WDM networks, wavelength-routed networks, optical CDMA, ultra high capacity WDM networks, bit-interleaved optical TDM, time-slotted optical TDM.

Students enrolled in OE593 must do project work on a topic selected by the instructor.

OE 594 Guided-Wave Optics 3R-3L-4C S Pre: OE 485 or SR/GR standing or consent of instructor

Theory of optical waveguides; waveguide modes; fabrication techniques; input and output coupling techniques; waveguide losses; waveguide gratings; electro-optic modulators; integrated optical detectors; applications of integrated optics.

OE 595 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); Review of interference and coherence; fringe visibility; third order aberrations; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Students must do additional project work on a topic selected by the instructor. Cross-listed with OE 495.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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Admissions

Academics

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News

Calendars

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Advanced Placement

Graduate Studies

Physics

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Note: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

PHPP Calculus III, PH111, PH112– Phast Physics 12R-3L-13C Pre: One year of college level calculus (BC Calculus or equivalent), one year of high school physics, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Phast Physics Selection Committee.

A 5-week intensive immersion into calculus and physics which covers the equivalent of Calculus III, and Physics I, II. Taught only to incoming freshman who have demonstrated outstanding ability in both calculus and physics. Review of single variable calculus, both differential calculus and integral calculus, as needed. Covers from MA113: vectors and parametric equations in three dimensions, functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems with applications of vectors, parametric equations, partial derivatives and multiple integrals. Covers from PH111, PH112: kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, conservation of energy and momentum, torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, with relevant laboratory experiments.

PH 111 Physics I 3.5R-1.5L-4C F, W Coreq: MA 111

Kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, strong and weak nuclear forces, conservation of energy and momentum, relevant laboratory experiments.

PH 112 Physics II 3.5R-1.5L-4C W, S Pre: PH 111 and MA 111; Co: MA 112

Torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, relevant laboratory experiments.

PH 113 Physics III 3.5R-1.5L-4C S, F Pre: PH 112 and MA 112; Coreq: MA 113

Sources of magnetic fields, Faraday's law, inductance electromagnetic waves, reflection and polarization, geometric and physical optics, introduction to relativity, relevant laboratory experiments.

PH 200 Career Preparation 1R-0L-1C W,S

This course is for physics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, MA200 and SV200.

PH 215 Introduction to CHAOS 2R-0L-2C W

What constitutes chaotic behavior, detection of chaos in real systems using phase space plots, Poincare sections, bifurcation plots, power spectra, Lyapunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Pre: MA 111, and PH 111 or EM 120

Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Pre: PH 111 or Coreq: EM 202; and Coreq: MA 112

Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Pre: MA 111, and PH 111 or EM 120

Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Pre: MA 111, and PH 111 or EM 120

Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Pre: PH 113 and Coreq: MA 211

Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Pre: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Pre: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Pre: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Pre: PH 113

The wave equation; electromagnetic waves; phase and group velocities; complex refractive index; dispersion, interference; interferometers and applications, optical interferometry; coherence; polarized light; Jones vectors/matrices; production of polarized light; birefringence, Fraunhofer diffraction; diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Pre: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Pre: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S, Arranged Pre: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W, Arranged Pre: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Pre: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Pre: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Pre: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Pre: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication,

transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Pre: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 330 Material Failure 3R-3L-4C W Pre: PH 113

Physical principles of instrumentation used for material failure analysis, including light microscopy, electron microscopy, and spectroscopy. Laboratory includes experiments and case studies using these instruments.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Pre: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schrodinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schrodinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Pre: PH 113, and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Cross-listed with PH 505.

PH 407 Solid State Physics 4R-0L-4C S (even years) Pre: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Pre: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Pre: MA 212, and JR/SR or Graduate standing

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory.

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Pre: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Pre: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Pre: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Pre: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Pre: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Pre: Consent of instructor

Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.



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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Robotics

ROBO 410 Robotics Capstone Design I 1R-6L-4C F
Pre for EE or CPE: ECE 362, and a co-requisite ME 430
Pre for ME: ME senior class standing, and co-requisites of ME 430 and ME 470
Pre for CS or SE: RH 330 and CSSE 374, and a co-requisite ME 430

ROBO 420 Robotics Capstone Design II 1R-6L-4C W
Pre: ROBO 410

ROBO 430 Robotics Capstone Design III 1R-6L-4C S
Pre: ROBO 420

Description: Interdisciplinary group robotics engineering project. This requires the carrying out, from inception to completion, of a robotics-related system development for an approved client. The focus for students from each major is on design appropriate to that major related to robotics. Teamwork activities are expected to involve coordination of multidisciplinary aspects of the project, team planning, leading, and reviewing of project progress versus risks. Engineering practices related to design include requirements and constraint analysis and management, design creation and documentation, prototyping, system construction and testing, following of engineering standards, and management of intellectual property. Technical completion and delivery to the client is expected.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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U.S. News

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Prospective Students

Current Students

Faculty and Staff

Alumni and Friends

Industry Partners

Trustees

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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Sophomore Engineering

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 211 Differential Equations (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 212 Matrix Algebra & Systems of Differential Equations (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,
- develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,
- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,

Aerospace Studies (Air Force ROTC)
Applied Biology & Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Military Science (Army ROTC)
Multi-Disciplinary Studies
Optical Engineering
Physics
Robotics
Sophomore Engineering

- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Pre: MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid & Thermal Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better

Conservation and accounting equations applied to fluid and thermal systems. Fluid and thermodynamic properties of pure substances. Open and closed systems hydrostatics. Dimensional analysis. Mechanical energy balance and pipe flow. Lift and drag.

ES 203 Electrical Systems; 3R-3L-4C; F,W,S; Pre: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better Co: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Pre: ES 202, ES 203 with a grade of C or better, OR ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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Community Members

Industry Partners
Trustees
Parents

Programs of Study

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Entrepreneurship Minor

Increasing globalization and the need for rapid implementation of innovations mean that that 21st Century engineers and scientists need to think like entrepreneurs. Everyone does not have to start a technology based business, but understanding the requirements of technology commercialization needs to be part scientific and technical thinking.

The Engineering Management Program has new programs in entrepreneurship for everyone to consider. These are intended to provide the basic tools for making new technology commercially successful.

The requirements of the undergraduate minor are 20 credits of the following:

- EMGT 427 Project Management
 - SV 350 Managerial Accounting
 - SV 356 Corporate Finance
 - IA 453 The Entrepreneur
 - IA 498 Technology Management & Forecasting
- or
- EMGT 423 Intro to Marketing for Technical Products

Up to 12 credits of EMGT 461, 462 and 463 may be substituted for the classes above. Other substitutions may be made with the approval of the head of the engineering management department. No more than one course may be transferred in to count toward the minor.

Participation in an entrepreneurial senior design experience approved by the head of the Engineering Management Department. This may be a part of the student's departmental design course, as well as participation in the Multidisciplinary, Entrepreneurial Design sequence



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Prospective Students
Current Students
Incoming Freshman

Faculty and Staff
Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

Course Catalog

Course Catalog 2016-2017

Course Catalog 2015-2016

Course Catalog 2014-2015

Course Catalog 2013-2014

Course Catalog 2012-2013

Course Catalog 2011-2012

Course Catalog 2010-2011

Course Catalog 2009-2010

The Rose-Hulman Course Catalog is the document of record for all Programs of Study and Course Descriptions for any given academic year.

For earlier versions of the Rose-Hulman Course Catalog please contact the [Registrar's office](#).

Archived Course Descriptions



2001

2003

2005

2006

2007

2008



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Information For

Prospective Students
Current Students
Incoming Freshman

Faculty and Staff
Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Applied Biology

The twenty-first century will see unparalleled advances in the biological sciences. Disciplines such as applied biology and biomedical engineering are burgeoning and will greatly impact the way we live in the future. The areas of functional genomics and proteomics will drive discoveries in molecular medicine, gene therapy and tissue engineering. Drug discovery will be facilitated by the elucidation of new target molecules and many pharmaceutical compounds will be produced using biological processes. Environmental management, remediation and restoration will also benefit from advances in applied biology. Biologists will be at the forefront of these advances and will drive the medical, agricultural, environmental and industrial applications of biological sciences.

The applied biology program will produce biologists with the chemistry, mathematics, and physics background needed to solve biotechnological problems in the coming decades. Those students wishing to strengthen their engineering skills can earn the area minor in biomedical engineering. Other students may choose to pursue a second major in [Biochemistry and Molecular Biology](#). The program will prepare graduates for professional careers in government and industrial research laboratories, and in the biotechnology and health-related industries.

Those wishing to continue their studies in graduate or health professions programs will be exceptionally well qualified to do so.

Applied Biology Plan of Study

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
AB	110	Cell Structure and Function	4	AB	210	Mendelian & Molecular Genetics	4
CHEM	111	General Chemistry I	4	CHEM	251	Organic Chemistry I	4
MA	111	Calculus I	5	PH	111	Physics I	4
CLSK	100	College & Life Skills	1	MA	212	Matrix Algebra and Systems of Differential Equations	4
			14				16
Winter Term				Winter Term			
			Credit				Credit
AB	120	Comparative Anatomy & Physiology	4	AB	220	Prokaryotic Cell & Molecular Biology	4
CHEM	113	General Chemistry II	4	CHEM	252	Organic Chemistry II	4
MA	112	Calculus II	5	PH	112	Physics II	4
BE	100	Problem Solving in the Biological Sciences and Engineering	4	HSS		Elective	4
			17				16

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

- Additional Programs of Study
- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Spring Term				Spring Term			
			Credit				Credit
AB	130	Evolution and Diversity	4	AB	230	Eukaryotic Cell & Molecular Biology	4
CHEM	115	General Chemistry III	4	CHEM	253	Organic Chemistry III	4
MA	113	Calculus III	5	PH	113	Physics III	4
RH	131	Rhetoric & Composition	4	MA	223	Engineering Statistics	4
			17				16

Junior Year				Senior Year			
Fall Term				Fall Term			
			Credit				Credit
AB	320	Ecology	4	AB	499	Thesis Research	4
		Free elective	4			Science/Technical	4
AB		Elective	4			Elective	
RH	330	Technical and Professional Communication		HSS		Elective	4
		or				Free elective	4
HSS		Elective	4				16
AB	301	Jr. Colloq	1	Winter Term			
			17				Credit

Winter Term				Winter Term			
			Credit				Credit
AB	330	Evolutionary Biology	4	AB	401	Senior Colloquium	2
CHEM	330	Biochemistry	4			Science/Technical Elective	4
AB		Elective	4	AB	499	Thesis Research	4
HSS		Elective		HSS		Elective	4
		or					14
RH	330	Technical and Professional Communication	4	Spring Term			
AB	302	Junior Colloquium	1				Credit
			17	AB		Elective	4
						Science/Technical Elective	4
				HSS		Elective	4
							12

Spring Term				Total credits required: 188			
			Credit				
AB	310	Plant Structure & Function	4				
AB	499	Thesis Research	4				
SV	304	Bioethics	4				
HSS		Elective	4				
			16				

An AB science/technical elective is any Rose-Hulman course that has a prefix of AB, BE, CHEM, CHE, CE, CSSE, ECE, GEOL, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required AB courses	52 credits
AB electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	

Required MA, CHEM, PH	12 credits
Required CLSK	63 credits
Sci/Tech electives	1 credits
Required BE course	12 credits
	4 credits

Total

188 credits

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility. Two faculty are directly involved with this program: Dr. Mark Brandt, assistant professor of chemistry, is the program coordinator and is a biochemist, and Dr. Richard Anthony, associate professor of applied biology, is a molecular biologist. Many other faculty in both the chemistry and applied biology departments assist with this curriculum.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required courses:

Course	Description	Hours
CHEM 111, 113, 115	General Chemistry	12
CHEM 251, 252, 253	Organic Chemistry	12
CHEM 330, 430, 433	Biochemistry	9
CHEM 361, 362 or CHEM 360 and CHE 303, 304	Physical Chemistry	8
AB 110, 120, 130	Biology	12
AB 210	Genetics	4
AB 220, 230	Molecular Biology	8
AB 411	Genetic Engineering	4
Total		69

Elective Courses

Choose 12 credits* from the following courses:

AB 330	Evolutionary Biology
AB 421	Applied Microbiology

AB 431	Genomics and Proteomics
AB 441	Virology
AB 451	Cancer Biology
AB 492	Directed Study in Applied Biology

CHEM 225	Analytical chemistry
CHEM 291	Introduction to Research
CHEM 331	Biochemistry II
CHEM 431	Biochemical Instrumentation
CHEM 451	Organic Structure Determination
CHEM 290	Chemical Research

Or

CHEM 490

PH 302	Biophysics
--------	------------

Total Credits for second major 81

*Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the AB electives listed, and 4 credits chosen from any AB or BE course.

STUDENTS WITH A MAJOR IN APPLIED BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above AB course (total: 29 hours required beyond Applied Biology major).

Applied Biology Area Minor

The Area Minor in Applied Biology is designed to allow students to enrich studies in their major area. Students wishing to apply another science, mathematics, or engineering discipline to investigate or solve problems in biological systems are encouraged to pursue the Area Minor in Applied Biology. With proper course selection, the Area Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Area Minor in Applied Biology has the following requirements.

1. All students must complete AB110 (Cell Structure and Function) or AB130 (Evolution and Diversity) and at least four more courses in applied biology (AB) or allied areas, above those courses already specifically required to fulfill the student's major.
 - a. At least three of the four electives must be AB courses.
 - b. At least three of the electives must be 200-level or above.Additional courses not listed in the approved allied areas can be considered on a case-by-case basis. See ABBE Department Head.
2. Students electing to pursue the Area Minor in Applied Biology must follow a plan of study that is approved by the Area Minor Advisor. Current advisor information and a form for the planning and approval of an area minor can be obtained from the ABBE Department secretary.
3. Allied area courses could include:
 - o BE 310 Analysis of Physiological Systems I
 - o BE 320 Analysis of Physiological Systems II
 - o BE/MA 482 Bioengineering Statistics
 - o BE 570 Introduction to Tissue Engineering
 - o CE 460 Introduction to Environmental Engineering
 - o CHE 545 Introduction to Biochemical Engineering
 - o CHEM 264 Environmental Chemistry
 - o CHEM 330 Survey of Biochemistry
 - o CHEM 430 Advanced Biochemistry
 - o PH 302 Biophysics
 - o SL 386 Human Evolution
 - o VA 373 Gender Issues

Biochemistry & Molecular Biology Area Minor

Completion of AB110, CHEM111, CHEM113 and CHEM115 or AB110, CHEM105 and CHEM107. In addition,

the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology or
AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering or AB431 - Genomics and Proteomics
- CHEM230 - Introduction to Organic Chemistry and Biochemistry or
CHEM251 - Organic Chemistry I and CHEM252 - Organic Chemistry II
- CHEM330 - Biochemistry
- CHEM430 - Advanced Biochemistry with the CHEM433 Biochemistry Laboratory



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Current Students
Incoming Freshman

Faculty and Staff
Alumni and Friends
Community Members

Industry Partners
Trustees
Parents

Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Biochemistry Plan of Study

Freshman Year		Sophomore Year	
Fall Term	Credit	Fall Term	Credit
CHEM111*General Chemistry I.....	4	CHEM251Organic Chemistry I	4
MA 111 Calculus I	5	PH 113Physics III.....	4
AB 110 Cell Structure & Function...	4	MA 212Matrix Algebra and Systems of Differential Equations.....	4
CLSK 100 College and Life Skills	1	AB 210Mendelian & Molecular Genetics.....	4
RH 131 Rhetoric and Composition or			
HSS Elective.....	4		
	<hr/> 18		<hr/> 16
Winter Term	Credit	Winter Term	Credit
CHEM113*General Chemistry II	4	CHEM200Career Preparation (take in winter or spring)	1
MA 112 Calculus II.....	5	CHEM252Organic Chemistry II	4
PH 111 Physics I.....	4	CHEM291Intro to Undergraduate Research.....	4
RH 131 Rhetoric & Composition or		MA 381Introduction to Probability with Applications to Statistics.....	4
HSS Elective.....	4	AB 220Prokaryotic Cell & Mol. Biology.....	4
	<hr/> 17		<hr/> 16 or 17
Spring		Spring	

- | |
|------------------------|
| Applied Biology |
| Biochemistry |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- | |
|---|
| Aerospace Studies (Air Force ROTC) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS)
(Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Military |
| Pre-Professional Programs |

Term	Credit	Spring Term	Credit
CHEM115 General Chemistry III	4	CHEM200Career Preparation (take in winter or spring)	1
MA 113 Calculus III.....	5	CHEM253Organic Chemistry III	4
PH 112 Physics II.....	4	CHEM225Analytical Chemistry	4
HSS Elective.....	4	AB 230Eukaryotic Cell & Mol. Biology.....	4
		HSS Elective.....	4
	<hr/> 17		<hr/> 16 or 17

Junior Year Fall Term	Credit	Senior Year Fall Term	Credit
CHEM326 Bioanalytical Chemistry.....	4	CHEM441 Inorganic Chemistry I.....	4
CHEM330 Biochemistry I....	4	CHEM401 Chemical Communication II.....	1
CHEM361 **Physical Chemistry I...	4	CHEM490 Chemistry Research.....	1
HSS Elective.....	4	##Advanced Chemistry or Biochemistry Elective	4
	<hr/> 16	Advanced Biology Elective .	4
		Free	4
		Elective.....	
			<hr/> 18

Winter Term	Credit	Winter Term	Credit
CHEM327 Advanced Analytical	4	CHEM402Chemical Communication III ..	1
CHEM362 **Physical Chemistry II...	4	CHEM490Chemistry Research.....	1
CHEM331 Biochemistry II.....	4	HSS Elective.....	4
CHEM400 Chemical Communication I.....	1	## Advanced Biology, Chemistry, Biochem.....	4
HSS Elective.....	4	Free	4
	<hr/> 17	Elective.....	
			<hr/> 14
Spring Term	Credit	Spring Term	Credit
CHEM363 Quantum Chemistry & Molecular Spectroscopy.	4	CHEM403Chemical Communication IV.....	1
CHEM430 Advanced Biochemistry	4	CHEM490Chemistry Research.....	1
CHEM433 Biochemistry Lab.....	1	HSS Elective.....	4
HSS Elective.....	4	Free	4
CHEM490#Research.....	1	Elective.....	
	<hr/> 14	Free	4
		Elective.....	
			<hr/> 14

Total credits required: 192

Notes:
Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113. Biochemistry majors may replace CHEM 111, CHEM 113, and CHEM 115 with CHEM 105, CHEM 107, and 4 additional credits of chemistry, which must include a 1 credit laboratory experience. The typical student will be well served by taking CHEM 115.

**CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441	4
Biochemistry	330, 331, 430, 433	13
Research & Literature	291, 490	7
Seminar	401, 402, 403	3
Career Preparation	200	1
Electives		8
Total		84

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total
Chemistry	76	8	84
Physics	12	0	12
Mathematics	23	0	23
Biology	20	0	20
Humanities and Social Sciences	4	32	36
Electives	0	16	16
College and Life Skills	1	0	1
Total	136	56	192

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
*CHEM105	Engineering Chemistry I	4
*CHEM107	Engineering Chemistry II	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE 465	Energy and the Environment	4
Total		28

*CHEM 105 and CHEM 107 can be substituted for CHEM111You may replace CHEM111, CHEM 113, and CHEM 115.

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors

Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
---------------	--------------	---------

CHEM225	Analytical Chemistry	
or CHEM253	Organic Chemistry III	4
CHEM330	Biochemistry I	
or CHEM361	Physical Chemistry I	4
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHEM465	Energy and the Environment	4
Total		24



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Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

- be able to design and conduct experiments, making measurements from both living and non-living systems.
- be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- be able to function in multidisciplinary teams in different roles.
- be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- have the skills required for self-learning.
- be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

The biomedical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year			Sophomore Year		
Fall Term		Credit	Fall Term		Credit
AB 110	Cell Structure and Function	4	ES 201	Conservation & Accounting Principles	4
PH 111	Physics I	4	CHEM 111	General Chemistry I	4
MA 111	Calculus I	5	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	ES 203	Electrical Systems	4
EM 104	Graphical Communication	2		Total	16
	Total	16			
Winter Term		Credit	Winter Term		Credit
AB 120	Comparative Anatomy & Physiology	4	ES 202	Fluid and Thermal Systems	3
PH 112	Physics II	4	ES 204	Mechanical Systems	3
MA 112	Calculus II	5	MA 212	Matrix Algebra and Systems of Differential Equations	4
BE 100	Problem Solving in the Biological Sciences and Engineering	4	CHEM 113	General Chemistry II	4
	Total	17	HSS	Elective	4
			Total		18
Spring Term		Credit	Spring Term		Credit
PH 113	Physics III	4	BE 201	Biomedical Measurements	4
RH 131	Rhetoric & Composition	4	AB 130	Evolution and Diversity	4
MA 113	Calculus III	5	ES 205	Analysis & Design of Engineering Systems	4
EM 121	Statics and Mechanics of Materials I	4	MA 223	Engineering Statistics	4
	Total	17	Total		16
Junior Year			Senior Year		
Fall Term		Credit	Fall Term		Credit
HSS	Elective	4	BE 410	Biomedical Engineering Design I	4
AB 205	Cellular Physiology	4	HSS	Elective	4
RH 330	Technical and Professional Communication	4		Free Elective	4
HSS					

	or		BE	Area Elective	4
	Elective			Total	16
EM 204	Statics and	4	Winter Term		Credit
	Mechanics of Materials II		BE 420	Biomedical Engineering	4
	Total	16		Design II	
Winter Term		Credit	HSS	Elective	4
BE 310	Physiological Systems I	4		Free Elective	4
BE 331	Biomechanics	3	BE	Area Elective	4
BE 351	Biomedical Engineering Lab	2		Total	16
BE 361	Biomaterials	3	Spring Term		Credit
HSS	Elective	4	BE 430	Biomedical Engineering	2
	or			Design III	
RH 330	Technical and		HSS	Elective	4
	Professional			Free Elective	4
	Communication		BE	Area Elective	4
	Total	16		Total	14
Spring Term		Credit	Total credits required:		192
SV 304	Bioethics	4			
BE 320	Physiological Systems II	4			
BE 390	Principles of Biomedical	2			
	Engineering Design				
BE	Area	4			
	Total	14			

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the ABBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 417	Advanced Materials
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanincs
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both
**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols
BE 516	Introduction to MEMS
BE 435/535	Biomedical Optics
BE 555	Electrophysiology

ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course Title

ME 317**Design for Manufacturing
and

BE 317** Design for Biomedical Manufacturing

BE 525 Biomedical Fluid Mechanics

BE 531 Biomechanics II

BE 534 Soft Tissue Mechanics

BE 539 Multiscale Biomechanics

BE 545 Orthopaedic Biomechanics

BE 550 Research Methods in Biomechanics

EM 403 Advanced Mechanics of Materials

ME 422 Finite Elements for Engineering Applications

ME 520 Computer-Aided Design and Manufacturing

ME 522 Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.
3. Complete the course, BE 499 Thesis Research, in which the thesis is written and submitted to the department, and an oral research presentation is given to a minimum of three departmental faculty members, including the student's advisor. Successful completion of the biomedical engineering thesis will be noted on the student's transcript.

Biomedical Engineering Area Minor

The biomedical engineering area minor is intended to provide a strong biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and the health care related fields.

In order to complete the requirements in the biomedical engineering area minor, a student must complete AB110 "Cell Structure and Function" and 16 credits from list shown below. At least three of the courses must have a BE prefix.

Biomedical Engineering Minor Electives

PH 302	4	Biophysics
AB 411	4>	Genetic Engineering
BE 310	4	Analysis of Physiological Systems I
BE 320	4	Analysis of Physiological Systems II
BE 331		Biomechanics
BE 340	4	Biomedical Instrumentation
BE 350	4	Biocontrol Systems
BE 351	2	Biomedical Engineering Lab *
BE 352	1	Biomechanics Lab *
BE 353	1	Biomaterials Lab *
BE 361	3	Biomaterials
BE 435/5354		Biomedical Optics
BE 482	4	Bioengineering Statistics
BE 510	4	Biomedical Signal and Image Processing
BE 525	4	Biomedical Fluid Mechanics
BE 531	4	Biomechanics II

BE 534	4	Soft Tissue Mechanics
BE 539	4	Multiscale Biomechanics
BE 541	4	Medical Imaging
BE 543	4	Neuroprosthetics
BE 545	4	Orthopaedic Biomechanics
BE 550	4	Research Methods in Biomechanics
BE 555	4	Electrophysiology
BE 560	4	Tissue-Biomaterial Interactions
BE 570	4	Introduction to Tissue Engineering


*Students getting credit for BE351 cannot get credit for BE352 or BE353.

In addition to courses on the above list, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

Basic Engineering Courses

- EM 121 Statics and Mechanics of Materials I
- EM 204 Statics and Mechanics of Materials II
- EM 301 Fluid Mechanics
- ECE 130Introduction to Logic Design
- ECE 200Circuits & Systems
- ES 201 Conservation & Accounting Principles
- ES 202 Fluid & Thermal Systems
- ES 203 Electrical Systems
- ES 204 Mechanical Systems
- CHE 201Conservation Principles and Balances
- CHE 202Basic Chemical Process Calculations
- CHE 301Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the Head of the Department of Applied Biology and Biomedical Engineering.



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Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve in three to five years.

- Apply a strong academic foundation to make early career contributions to the profession.
- Work in teams to tackle diverse, open-ended problems and to effectively communicate their findings.
- Apply skills for a long-term, productive career in an ever changing global environment.

Program Outcomes

Program Outcomes are statements that describe what students are expected to know and be able to do by the time of graduation.

1. Apply skills and knowledge to formulate and solve chemical engineering problems.
2. Design and conduct experiments and analyze and interpret the resulting data.
3. Define project specifications and design a process or system to meet those specifications.
4. Work effectively in teams.
5. Communicate effectively in presentations and reports.
6. Make appropriate use of computer-based tools, such as process simulators and numerical analysis packages.
7. Understand the ethical and professional responsibilities of a chemical engineer.
8. Understand how chemical engineering impacts the global society.
9. Be prepared to engage in life-long learning.
10. Understand how the chemical engineering profession is related to contemporary issues.

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)
Biochemistry & Molecular Biology (Second Major Only)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degree of Master of Science in chemical engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required, but that requirement may be waived in exceptional circumstances. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

Area Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 325 Mass Transfer
- CHE 314 Heat Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Area Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- AB110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then take 8 credit hours from the following list of electives (the courses cannot also be used towards another minor or second major):

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology or
AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering
- AB421 - Applied Microbiology
- AB431 - Genomics and Proteomics
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary

Chemical Engineering

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)

Fall Term	Credit
CHEM111General Chemistry I*.....	4
CLSK 100College & Life Skills	1
EM 104Graphical Communications.	2
RH 131Rhetoric & Composition	4
MA 111Calculus I	5
	<hr/> 16

Winter Term	Credit
CHEM113General Chemistry II*.....	4
PH 111Physics I.....	4
HSS Elective.....	4
MA 112Calculus II	5
	<hr/> 17

Spring Term	Credit
CHE 110Programming & Computation for Chemical Engineers.....	2
CHEM115General Chemistry III.....	4
EM 103Introduction to Design	2
MA 113Calculus III.....	5
PH 112Physics II.....	4
	<hr/> 17

Summer Intern/Co-op
Sophomore Year (A1 Schedule)

Fall Term	Credit
CHE 200 Career Preparation I.....	0
CHE 201 Conservation Principles and Balances.....	4
CHEM251 Organic Chemistry I	4
MA 211 Differential Equations	4
EM 101Statics I	2
	<hr/> 14

Winter Term	Credit
CHE 202 Basic Chemical Process Calculations	4
CHEM252 Organic Chemistry II	4
MA 212 Matrix Algebra and Systems of Differential Equations.....	4
HSS Elective	4
	<hr/> 16

Spring Term	Credit
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Freshman Year (A2 Schedule)

Fall Term	Credit
CHEM111General Chemistry I.....	4
CLSK 100College & Life Skill	1
EM 104Graphical Communications.	2
RH 131Rhetoric and Composition .	4
MA 111Calculus I	5
	<hr/> 16

Winter Term	Credit
CHEM113General Chemistry II.....	4
PH 111Physics I.....	4
HSS Elective.....	4
MA 112Calculus II.....	5
	<hr/> 17

Spring Term	Credit
CHE 110Programming & Computation for Chemical Engineers.....	2
CHEM115General Chemistry III*	4
EM 103Introduction to Design	2
MA 113Calculus III.....	5
PH 112Physics II.....	4
	<hr/> 17

Summer Intern/Co-op
Sophomore Year (A2 Schedule)

Fall Term	Credit
CHE 200 Career Preparation I.....	0
CHE 201 Conservation Principles and Balances.....	4
CHEM251 Organic Chemistry I	4
MA 211 Differential Equations	4
EM 101Statics I	2
.....	
	<hr/> 14

Winter Term	Credit
CHE 202 Basic Chemical Process Calculations	4
CHEM252 Organic Chemistry II	4
MA 212 Matrix Algebra and Systems of Differential Equations.....	4
HSS Elective	4
	<hr/> 16

CHE 301 Fluid Mechanics.....	4	Spring		Credit
CHE 303 Chemical Engineering		Term		
Thermodynamics.....	4	MA 223 Engineering Statistics I.....	4	
Elective (Approved)	4	CHEM225 Analytical Chemistry I.....	4	
HSS Elective.....	4	HSS Elective.....	4	
		CHE 315Materials Science	4	
	16		
Summer Intern/Co-op				16
Junior Year (A1 Schedule)		Summer Intern/Co-op		
Fall Term	Credit	Junior Year (A2 Schedule)		
		Fall Term	Credit	
CHE 300Career Preparation II	0	CHE 300Career Preparation II	0	
CHE 304Multi-Component		CHE 301Fluid Mechanics.....	4	
Thermodynamics	4	CHE 303Chemical Engineering		
CHE 314Heat Transfer.....	4	Thermodynamics	4	
CHE 315Materials Science	4	Elective	4	
CHEM225Analytical Chemistry I.....	4	(approved).....		
	16	RH 330Technical and Professional	4	
		Communication		
				16
Winter	Credit	Winter		
Term		Term	Credit	
CHE 325Mass Transfer.....	4	CHE 304Multi-Component		
CHEM360Intro Physical Chemistry...	4	Thermodynamics.....	4	
MA 223Engineering Statistics I.....	4	CHE 314Heat Transfer.....	4	
RH 330Technical and Professional	4	ECE 206Elements of Electrical		
Communication		Engineering	4	
	16	HSS Elective.....	4	
				16
Spring	Credit	Spring		
Term		Term	Credit	
CHE 404Kinetics & Reactor Design	4	CHE 325Mass Transfer.....	4	
CHE 411Chemical Engineering Lab	3	CHE 411Chemical Engineering Lab	3	
I..		I.		
ECE 206Elements of Electrical		CHEM360Intro Physical Chemistry...	4	
Engineering	4	HSS Elective.....	4	
HSS Elective.....	4			15
	15			
Summer Intern/Co-op				15
Senior Year (A1 Schedule)		Summer Intern/Co-op		
Fall Term	Credit	Senior Year (A2 Schedule)		
		Fall Term	Credit	
CHE 409 Professional Practice	1	CHE 404 Kinetics & Reactor Design.	4	
CHE 412 Chemical Engineering Lab II	4	CHE 409 Professional Practice	1	
CHE 416 Design I	4	CHE 412 Chemical Engineering Lab	4	
Elective (Free).....	4	II		
Elective (CHE)	4	CHE 416 Design I	4	
	17	Elective (Free).....	4	
				17
Winter	Credit			

Term		Winter	
		Term	Credit
CHE 413	Chemical Eng. Lab III	CHE 413	Chemical Eng. Lab III
CHE 417	Design II	CHE 417	Design II
CHE 440	Process Control.....	CHE 440	Process Control.....
HSS	Elective.....	HSS	Elective.....
			16
			16
Spring		Spring	
Term		Term	Credit
CHE 418	Design III.....	CHE 418	Design III.....
HSS	Elective.....	HSS	Elective.....
HSS	Elective.....		Elective
	Elective (Approved)		(CHE).....
	Elective (CHE).....		Elective (CHE).....
			Elective (Approved)
			18
			18
Total credits required: 194		Total credits required: 194	

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM 111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 465 Energy and the Environment
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in an area of concentration. Some areas of concentration are Engineering Analysis (for students who would like to pursue a graduate degree), Chemistry and Life Sciences, Biotechnology, Material Science, Mathematical Modeling and Simulation, Computer Applications, Semiconductor Materials and Devices, and Environmental Management.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although a minimum of eight credit hours are recommended in an area of concentration, students are encouraged to take all the 20 credit hours of electives in an area of concentration. In

many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering or toward a certificate in semiconductor materials and devices.

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward a technical elective.



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include applied biology, chemical engineering and mathematics.

Chemistry Plan of Study

Freshman Year	
Fall Term	Credit
CHEM111* General Chemistry I.....	4
MA 111 Calculus I	5
AB 110**Biology	4
CLSK 100 College and Life Skills	1
RH 131 Rhetoric and Composition	
or	
HSS Elective.....	4
	18

Winter	
Term	Credit
CHEM113* General Chemistry II	4
MA 112 Calculus II.....	5
PH 111 Physics	4
I.....	
RH 131 Rhetoric and Composition	
or	
HSS Elective.....	4
	17

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Spring Term		Credit
CHEM115	General Chemistry III	4
MA 113	Calculus III.....	5
HSS	Elective.....	4
PH 112	Physics II.....	4
		17

Sophomore Year Fall Term		Credit
CHEM251	Organic Chemistry I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
PH 113	Physics III.....	4
	Free Elective.....	4
		16

Winter Term		Credit
CHEM200	Career Preparation (take in winter or spring)	1
CHEM252	Organic Chemistry II	4
CHEM291	Intro to Undergraduate Research.....	4
MA 381	Introduction to Probability with Applications to Statistics.....	4
	Free Elective.....	4
	16 or 17	

Spring Term		Credit
CHEM200	Career Preparation (take in winter or spring)	1
CHEM253	Organic Chemistry III	4
CHEM225	Analytical Chemistry I	4
HSS	Elective.....	4
	Free Elective.....	4
	16 or 17	

Junior Year Fall Term		Credit
CHEM326	Bioanalytical Chemistry.....	4
CHEM361	***Physical Chemistry I....	4
CHEM330	Biochemistry I.....	4
HSS	Elective.....	4
		16

Winter Term		Credit
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CHEM327	Advanced Analytical	4
CHEM362	***Physical Chemistry II...	4
CHEM400	Chemical Communications I....	1
HSS	Elective.....	4
	Free Elective.....	4
		17

Spring Term		Credit
CHEM363	Quantum Chemistry & Molecular Spectroscopy.	4
CHEM451	Organic Structure Determination.....	4
HSS	Elective.....	4
	Free Elective.....	4
CHEM490#	Research.....	1
		17

Senior Year Fall Term		Credit
CHEM441	Inorganic Chemistry I.....	4
CHEM401	Chemical Communications II....	1
CHEM490	Research.....	1
	Chemistry Elective	4
	Free Elective.....	4
		14

Winter Term		Credit
CHEM442	Inorganic Chemistry II.....	4
CHEM402	Chemical Communications III....	1
CHEM490	Research.....	1
HSS	Elective.....	4
	Chemistry Elective (400-level)##.....	4
		14

Spring Term		Credit
CHEM403	Chemistry Seminar III.....	1
CHEM490	Research.....	1
HSS	Elective.....	4
	Free Elective.....	4
	Free Elective.....	4
		14

Total credits required: 192

Notes:
Two degree or double major programs in chemistry and biochemistry is not allowed.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113. Chemistry majors may replace CHEM 111 and CHEM 113 with CHEM 105 and CHEM 107. These courses must be taken in these combinations. That is, CHEM 111 and CHEM 113, or CHEM 105 and CHEM 107.

**AB120 or AB130 may be substituted for AB110.

***CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441, 442	8
Biochemistry	330	4
Organic Structure Determination	451	4
Seminar	401, 402, 403	3
Research & Literature	291, 490	7
Career Preparation	200	1
Electives		8
Total		83

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total
Chemistry	75	8	83
Physics	12	0	12
Mathematics	23	0	23
Biology	4	0	4
Humanities and Social Sciences	4	32	36
Electives	0	36	36
College and Life Skills	1	0	1
Total	119	76	195

Area Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in applied biology or chemical engineering are different from those majoring in other disciplines.

Area Minor in Chemistry for Most Students

Course Number	Course Title	Credits
*CHEM107	Engineering Chemistry II	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM252	Organic Chemistry II	4
	**Approved List of Chemistry Electives	8
Total		24

*You may replace CHEM111 and CHEM113 for CHEM105 and CHEM107. These courses must be taken in these combinations. That is, CHEM111 and CHEM113, or CHEM105 and CHEM107

**Approved list of chemistry electives include CHEM115, CHEM253, CHEM290 (up to two credit hours), CHEM291, or any 300 or 400 level chemistry courses.

Area Minor in Chemistry for Chemical Engineering and Applied Biology Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	4
CHEM253	Organic Chemistry III	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student's major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students


Course Number	Course Title	Credits
*CHEM105	Engineering Chemistry I	4
*CHEM107	Engineering Chemistry II	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		28

*CHEM 105 and CHEM 107 can be substituted for CHEM111You may replace CHEM111, CHEM 113, and CHEM 115.

Environmental Chemistry Minor for Chemical Engineers and Applied Biology Majors

Environmental Certificate for Chemistry and Biochemistry Majors

Course Number	Course Title	Credits
CHEM225	Analytical Chemistry	
or CHEM253	Organic Chemistry III	4
CHEM330	Biochemistry I	
or CHEM361	Physical Chemistry I	4
CHEM303	Chemical Engineering Thermodynamics	4
CHEM264	Introduction to Environmental Science	4
CHEM371	Environmental Analytical Chemistry	4
CHE465	Energy and the Environment	4
Total		24

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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society's need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department’s Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department's Program
Educational Objectives and Student Learning Outcomes*

Graduates will demonstrate the ability to perform essential engineering functions in the design, management, or construction industry. Supporting learning outcomes are as follows:

- **Technical Core** – Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
- **Experiments** – Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.
- **Engineering Problems** – Develop problem statements and solve well-defined engineering problems in four technical areas appropriate to civil engineering.
- **Engineering Impact** – Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- **Contemporary Issues** – Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.

Graduates will demonstrate the ability to design/construct complex engineering systems in the broad-based

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

engineering industry. Supporting learning outcomes are as follows:

- **Design** – Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- **Multidisciplinary** – Function effectively as a member of a multidisciplinary team.
- **Professional/Ethical** –Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- **Communication** – Organize and deliver effective verbal, written, and graphical communications.
- **Engineering Tools** – Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.

Graduates will demonstrate their potential for technical leadership and management. Supporting learning outcomes are as follows:

- **Life Long Learning** – Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- **Leadership** – Apply leadership principles to direct the efforts of a small group.
- **Service** – Use one's time and skills to benefit an individual or community without cost to the recipient.
- **Project Management** – Explain key concepts in project management, and develop solutions to well-defined project management problems.
- **Business and Public Administration** – Explain key concepts and processes used in business, public policy, and public administration.
- **Cultural and Global Awareness** – Analyze and interpret cultural perspectives and social systems that define human characteristics.

* The civil engineering program uses the term “educational objective” to describe the expected accomplishments of our students in three to five years following graduation. The term “student learning outcome” is used to describe knowledge and skills at the time of graduation.

Civil Engineering Plan of Study

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
MA	111	Calculus I	5	MA	211	Differential Equations.....	4
PH	111	Physics I.....	4	CHEM	105	Engineering Chemistry I.....	4
RH	131	Rhetoric and Composition or Elective (HSS).....	4	EM	202	Dynamics Elective (HSS).....	4
EM	104	Graphical Communications.	2	CE	201	Engineering Surveying II...	2
CLSK	100	College and Life Skills	1				18
			16				
Winter Term				Winter Term			
			Credit				Credit
MA	112	Calculus II.....	5	MA	212	Matrix Algebra and Systems of Differential Equations.....	4
PH	112	Physics II..... Elective (HSS) or	4	EM	203	Mechanics of Materials Elective (HSS).....	4
RH	131	Rhetoric & Composition....	4	CHEM	107	Engineering Chemistry II	4
CE	110	Computer Applications and GIS.....	4				16
				Spring Term			
							Credit

MA	223	Statistics for Engineers.....	4
EM	301	Fluid Mechanics.....	4
CE	210	C.E. Computer Applications	2
CE	320	C.E. Materials	4
			<hr/> 14
Senior Year			
Fall Term			Credit
CE	489	C.E. Design & Synthesis ...	2
		*Elective (Technical)	4
CE	450	C.E. Codes & Regulations..	4
		Elective (HSS).....	4
		Elective (HSS).....	4
			<hr/> 18
Winter Term			Credit
CE	489	C.E. Design & Synthesis (continued).....	4
CE		**C.E. Elective.....	4
		*Elective (Technical)	4
CE	303	Engineering Economy	4
			<hr/> 16
Spring Term			Credit
CE	489	C.E. Design & Synthesis (continued).....	2
		*Elective (Technical)	4
		Elective (HSS).....	4
		Elective (HSS).....	4
CE	400	Career Preparation Seminar.	0
			<hr/> 1

RH	330	Technical and Professional Communication..	4	Total credits required: 194
CE	461	Environmental Engineering	2	
		Lab.....	2	
				<hr/>
				15

*A Technical elective is any four (4) credit course in chemistry, computer science, engineering, life science, geology, mathematics, or physics.

**Student shall choose 1 of the following courses as the CE elective:

- CE 421 Structural Mechanics II
- CE 442 Cost Engineering
- CE 563 Unit Operations in Environmental Engineering

Environmental Engineering Area Minor

The Environmental Engineering Area minor includes 3 required courses and 3 elective courses. The required courses provide an introduction to the overall field of environmental engineering. The elective courses allow the student to tailor the minor to their academic majors and special interests.

The 3 required courses are as follows:

- | | |
|----------|---|
| CHEM 264 | Introduction to Environmental Science |
| CE 460 | Introduction to Environmental Engineering |
| CE 471 | Water Resources Engineering |

And 3 electives from the following list:

- | | |
|----------------|--|
| CE 561/CHE 450 | Air Pollution Control |
| CE 562 | Treatability Studies |
| CE 563/CHE 461 | Unit Operations in Environmental Engineering |
| CE 564 | Environmental Chemistry |
| CE 565 | Solid and Hazardous Waste Regulation and Treatment |
| CE 566 | Environmental Management |
| CE 567 | Applied Hydrologic Modeling |
| CE 568 | Applied Contaminant Transport Modeling |
| CE 569 | Environmental Systems Optimization |
| CE 573 | Groundwater Analysis |
| CE 590 | Special Problems |
| CHE 470 | Safety, Health, and Loss Prevention |
| SV 354 | Environmental Economics |
| ME 331 | Energy-Material Resource Recovery and Utilization |
| ME 513 | Environmental Noise |
| AB 320 | Ecology and Environmental Biology |

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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

Computer Engineering Student Learning Outcomes

The mission statement for the ECE (Electrical & Computer Engineering) Department: To provide students in ECE a rigorous learning experience that prepares them for professional careers.

CPE Student Learning Outcomes: CPE student learning outcomes are designed to instill in our graduates the skills appropriate to their professions and life-long learning. The CPE program uses the term “student learning outcomes” to describe knowledge and skills at the time of graduation that are derived from the objectives.

Holistic Education: Computer Engineering graduates shall be prepared to practice the profession of engineering using a systems perspective broad enough to encompass technological, economic, ethical, environmental, social, and human issues, shall have demonstrated a facility for independent learning, and shall be prepared for continued professional development.

- H1: Demonstrate a facility for independent learning
- H2: Be prepared for continued professional development
- H3: Effective communications skills
- H4: Contemporary Issues
- H5: Role of professional in global society

Technical Preparation: Electrical and Computer Engineering graduates shall demonstrate technical depth and breadth in their discipline.

- T1: General engineering science core plus a discipline-specific technical core
- T2: Effective use of contemporary tools of the engineering profession

Design & Professional Practice: Computer Engineering graduates shall have participated in design experiences including a comprehensive, industrially-oriented design project, oral presentations, and written communications.

- D&P: Client sponsored team design experience

Computer Engineering Plan of Study

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
PH	111	Physics I.....	4	MA	211	Differential Equations	4
MA	111	Calculus I	5	CSSE	232	Computer Architecture I	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

CLSK	100	College and Life Skills	1	
RH	131	Rhetoric & Composition or		
HSS		Elective	4	
ECE	160	Engineering Practice	<u>2</u> 16	
Winter Term			Credit	
PH	112	Physics II.....	4	
MA	112	Calculus II.....	5	
CSSE	120	Introduction to Software Development	4	
HSS		Elective or		
RH	131	Rhetoric & Composition.....	4	
			<u>17</u>	
Spring Term			Credit	
PH	113	Physics III	4	
MA	113	Calculus III.....	5	
ECE	130	Introduction to Logic Design	4	
CSSE	220	Object-Oriented Software Development	4	
			<u>17</u>	
Junior Year Fall Term			Credit	
MA	275	Discrete & Combinational Algebra I	4	
ECE	351	Analog Electronics	4	
ECE	333	Digital Systems	4	
RH	330	Technical and Professional Communication..	4	
			<u>16</u>	
Winter Term			Credit	
ECE	300	Signals & Systems	4	
ECE	331	Embedded System Design	4	
ECE	332	Computer Architecture II Math/Science Elective	<u>4</u> 16	
Spring Term			Credit	
ECE	380	Discrete Time & Continuous Systems	4	

ECE	203	DC Circuits	4	
CHEM	105	Engineering Chemistry I	<u>4</u> 16	
Winter Term			Credit	
MA	212	Matrix Algebra and Systems of Differential Equations	4	
CSSE	332	Operating Systems.....	4	
ECE	204	AC Circuits	4	
HSS		Elective	<u>4</u> 16	
Spring Term			Credit	
MA	381	Introduction to Probability with Applications to Statistics	4	
ECE	250	Electronic Device Modeling	4	
ECE	205	Dynamical Systems	4	
HSS		Elective	4	
			<u>16</u>	
Senior Year Fall Term			Credit	
ECE	460	Engineering Design I Tech Elective Area Elective	3 4 4	
HSS		Elective	<u>4</u> 15	
Winter Term			Credit	
ECE	461	Engineering Design II Tech Elective Area Elective	4 4 4	
HSS		Elective	<u>4</u> 16	
Spring Term			Credit	
ECE	462	Engineering Design III Area Elective	2 4	
HSS		Elective	<u>4</u>	

ECE	342	Introduction to Electromagnetic Compatibility	4	Free Elective	4
ECE	362	Principles of Design	3	Free Elective	4
HSS			4		
			15	Total credits required: 194	

Area Electives

An area elective course is:

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Elective

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

Notes:

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, geology or physics course as a math science elective except those courses that are cross-referenced with any engineering courses.

Computer Engineering Core Courses

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE160	Engineering Practice	2
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Signals & Systems	4
ECE331	Embedded System Design	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4
ECE342	Introduction to Electromagnetic Compatibility	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE380	Discrete Time & Continuous Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

Second Major in Computer Engineering

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.

CPE Second Major

Course Number	Course Name	Credit
ECE 130	Introduction to Logic Design	4
ECE 203	DC Circuits	4

ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 250	Electronic Device Modeling	4
ECE 300	Signals & Systems	4
ECE 331	Embedded System Design	4
ECE 332	Computer Architecture II	4
ECE 333	Digital Systems	4
ECE 342	Introduction to Electromagnetic Compatibility	4
ECE 351	Analog Electronics	4
ECE 380	Discrete Time & Continuous Systems	4
CSSE 120	Introduction to Software Development	4
CSSE 220	Object-Oriented Software Development	4
CSSE 232	Computer Architecture I	4
CSSE 332	Operating Systems	4
Total		64

Area Minor in Electrical and Computer Engineering (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Fred Berry

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE205	Dynamical Systems	4
ECE300	Signals and Systems	4
ECE380	Discrete Time and Continuous Systems	4
ECE310	Communication Systems	4

Example Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits
ECE130	Introduction to logic Design	4
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical

communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman. All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

- 1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
- 2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
- 3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Computer Science

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

Computer Science Program Educational Objectives

- | |
|------------------------|
| Applied Biology |
| Biochemistry |
| Biomedical Engineering |
| Chemical Engineering |
| Chemistry |
| Civil Engineering |
| Computer Engineering |
| Computer Science |
| Economics |
| Electrical Engineering |
| Engineering Physics |
| Mathematics |
| Mechanical Engineering |
| Optical Engineering |
| Physics |
| Software Engineering |

Additional Programs of Study

- | |
|---|
| Aerospace Studies (Air Force ROTC) |
| Biochemistry & Molecular Biology (Second Major Only) |
| Computational Science Major (CPLS)
(Second Major Only) |
| International Studies Major (IS) (Second Major Only) |
| Military |
| Pre-Professional Programs |

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

- 1. Graduate students and researchers.
- 2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
- 3. Entrepreneurial leaders.
- 4. Business and technological leaders within existing organizations.
- 5. Actively involved in social and professional service locally, nationally, and globally.
- 6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
- 7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Program Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

- 1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
- 2. Anticipate complexities and problems involved in the development of large software systems
- 3. Analyze requirements, design software that satisfies those requirements, and implement that software
- 4. Analyze problems using ideas of problem complexity, models of computation, and decidability
- 5. Design algorithms using a variety of paradigms
- 6. Analyze algorithms in terms of correctness, as well as time and space efficiency
- 7. Communicate effectively, both verbally and in writing
- 8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
- 9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- 10. Collaborate effectively in small teams
- 11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- 12. Explain the impact of globalization on computing and software engineering
- 13. Recognize the need for, and engage in, lifelong learning

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

There are many alternatives to the schedule below. Students with special interests or opportunities (e.g., advanced placement) should determine what schedule is best for their own plan of study by examining schedules at the department's web site: www.cs.rose-hulman.edu.

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
CSSE	120	Introduction to Software Development ..	4	CHEM	105	Engineering Chemistry I ...	4
MA	111	Calculus I	5	CSSE	232	Computer Architecture I ...	4
PH	111	Physics I	4	MA	212	Matrix Algebra and Systems of Differential Equations	4
RH	131	Rhetoric & Composition ...	4	MA	275	Discrete & Combinatorial Algebra I	4
CLSK	100	College and Life Skills	1				16
			18	Winter Term			
Winter Term							Credit
			Credit				
CSSE	220	Object-Oriented Software Development	4	CSSE	230	Data Structures and Algorithm Analysis	4
				CSSE	333	Database Systems	4

MA	112	Calculus II	5		MA	375	Discrete & Combinatorial Algebra II	4
PH	112	Physics II	4		HSS		Elective	4
HSS		Elective	4					16
			17		Spring Term			Credit
Spring Term			Credit		CSSE 304	Programming Lang. Con. ..		4
ECE	130	Introduction to Logic Design	4		ECE	332	Computer Architecture II	4
MA	113	Calculus III	5		MA	381	Introduction to Probability with Statistical Applications	4
HSS		Elective	4		RH	330	Technical and Professional Communication	4
Science		Elective	4					16
			17		Senior Year			
Junior Year					Fall Term			Credit
CSSE	371	Software Requirements & Specification	4		CSSE 487	Senior Research Project I or		
CSSE/MA473		Design and Analysis of Algorithms	4		CSSE 497	Senior Project I or		
CSSE		Elective	4		CSSE 494	Senior Thesis I	4	
HSS		Elective	4		CSSE	Elective	4	
			16		HSS	Elective	4	
Winter Term			Credit		Free	Elective	4	
CSSE	332	Operating Systems	4					16
CSSE	374	Software Architecture and Design	4		Winter Term			Credit
CSSE/MA474		Theory of Computation ..	4		CSSE 488	Senior Research Project II or		
HSS		Elective	4		CSSE 498	Senior Project II or		
			16		CSSE 495	Senior Thesis II.....	4	
Spring Term			Credit		CSSE	Elective	4	
CSSE		Elective	4		HSS	Elective	4	
		Technical Elective	4			Technical Elective	4	
Free		Elective	4					16
Free		Elective	4		Spring Term			Credit
			16		CSSE 489	Senior Research Project III or		
CSSE electives cannot include any of CSSE 372, 373, and 375 through 377. Science elective is any CHEM, PH, GEOL, or AB courses totaling at least 4 credits.					CSSE 499	Senior Project III or		
					CSSE 496	Senior Thesis III	4	
					Free	Elective	4	

Free	Elective	4
	
		12

Total credits required: 192

HSS electives must be distributed as required by HSS.

Summary of graduation requirements for the computer science major
To complete the major in computer science a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE130, ECE332; PH111, PH112; CHEM105; RH131, RH330; CLSK100.
2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 377. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
7. A total of 192 credits.

Area Minor in Computer Science


Advisor: Dr. Laxer

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

- CSSE120 Introduction to Software Development
- CSSE220 Object-Oriented Software Development
- CSSE230 Data Structures and Algorithm Analysis

Four additional courses in computer science numbered above 200. None of these may be CSSE 371-377.



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Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories

2. use economic theory to define, analyze and solve a wide range of problems.

3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.

4. communicate complex economics topics in both oral and written form.

5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	Credit 5	Fall Term		Credit
CLSK 100	College & Life Skills	1	MA 211	Differential Equations	4
RH 131	Rhetoric and Composition	4		Economics Elective	4
	or			*HSS Elective	4
HSS	Elective			Physical or Life Science	4
	Physical or Life Science	4		Total	16
	Total	14	Winter Term		Credit
Winter Term			MA 212		
MA 112	Calculus II	5		Matrix Algebra and Systems	4
CSSE 120	Introduction to	4		of Differential Equations	
	Software Development			Economics Elective	4
	Physical or Life Science	4		*HSS Elective	4
RH 131	Rhetoric and Composition	4		Physical or Life Science	4
	or			Total	16
HSS	Elective		Spring Term		Credit
	Total	17	MA 381	Introduction to Probability	4
Spring Term				with Applications	
MA 113	Calculus III	5	or	to Statistics	
SV 151	Principles of Economics	4	MA 223	Engineering Statistics	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Physical or Life Science	4	Economics Elective	4
*HSS Elective	4	*HSS Elective	4
Total	17	Physical or Life Science	4
		Total	16

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

- 1. 20 credits of required Economics courses:
SV151 Principles of Economics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX496 Seminar for HSS Senior Projects
XX497 Directed Study for HSS Senior Project
- 2. 24 additional credits in Economics electives.
- 3. 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA211, 212 Differential Equations , and Matrix Algebra and Systems of Differential Equations
MA223 Engineering Statistics I or
MA381 Introduction to Probability
- 4. 12 additional credits in Mathematics other than MA351-356.
- 5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
- 6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
- 7. 4 credits in Engineering Management
- 8. 4 credits in Computer Science: CSSE 120
- 9. CLSK 100 (1 credit) and SV 200 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
SV 200	1
TOTAL	193



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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

Electrical Engineering Student Learning Outcomes

The mission statement for the ECE (Electrical & Computer Engineering) Department: To provide students in ECE a rigorous learning experience that prepares them for professional careers.

EE Student Learning Outcomes: EE student learning outcomes are designed to instill in our graduates the skills appropriate to their professions and life-long learning. The EE program uses the term student learning outcomes to describe knowledge and skills at the time of graduation that are derived from the objectives.

Holistic Education: Electrical Engineering graduates shall be prepared to practice the profession of engineering using a systems perspective broad enough to encompass technological, economic, ethical, environmental, social, and human issues, shall have demonstrated a facility for independent learning, and shall be prepared for continued professional development.

- H1: Demonstrate a facility for independent learning
- H2: Be prepared for continued professional development
- H3: Effective communications skills
- H4: Contemporary Issues
- H5: Role of professional in global society

Technical Preparation: Electrical and Computer Engineering graduates shall demonstrate technical depth and breadth in their discipline.

- T1: General engineering science core plus a discipline-specific technical core
- T2: Effective use of contemporary tools of the engineering profession

Design & Professional Practice: Electrical Engineering graduates shall have participated in design experiences including a comprehensive, industrially-oriented design project, oral presentations, and written communications.

- D&P: Client sponsored team design experience

Electrical Engineering

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
PH	111	Physics I.....	4	MA	211	Differential Equations	4
MA	111	Calculus I.....	5	CHEM	105	Engineering Chemistry I	4
CLSK	100	College and Life Skills	1	ECE	203	DC Circuits	4
				ECE	230	Microcontrollers and Computer Architecture	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

.....				<hr/>	
RH	131	Rhetoric & Composition			16
or					
HSS		Elective	4		
ECE	160	Engineering Practice	2	Winter Term	Credit
<hr/>					
16				MA	212
				Matrix Algebra and	
				Systems of Differential	
				Equations	
				Math/Science Elective	
					4
				ECE	204
				AC Circuits	
					4
				HSS	
				Elective	
					4
<hr/>					
16					
Winter Term			Credit		
PH	112	Physics	4		
II.....					
MA	112	Calculus	5		
II.....					
ECE	130	Introduction to Logic	4		
Design					
RH	131	Rhetoric & Composition		Spring Term	Credit
or					
HSS		Elective	4		
<hr/>					
17					
Spring Term			Credit		
PH	113	Physics III	4		
.....					
MA	113	Calculus	5		
III.....					
HSS		Elective	4		
CSSE	120	Introduction to Software	4		
Development					
<hr/>					
17					
Junior Year				Senior Year	
Fall Term				Fall Term	
				Credit	
ECE	300	Signals & Systems	4	ECE	460
ECE	370	Power & Energy Systems		Engineering Design I	
or					3
ECE	371	Sustainable Energy	4		Tech Elective
Systems					4
ECE	340	Electromagnetic Fields	4		Area Elective
RH	330	Technical and	4	HSS	Elective
Professional					4
Communication				<hr/>	
<hr/>				15	
16					
Winter Term			Credit	Winter Term	Credit
ECE	380	Discrete Time &	4	ECE	461
Continuous Systems				Engineering Design II	
ECE	351	Analog Electronics	4		4
ECE	341	Electromagnetic Waves	4		Tech Elective
Math/Science Elective					4
<hr/>					Area Elective
16				HSS	Elective
					4
				<hr/>	
				16	
				Spring Term	Credit
ECE	462	Engineering Design III	2		
Free Elective					4
<hr/>					Free Elective
					4

					HSS	Area Elective	4
Spring Term	Credit					Elective	4
ECE 310	Communications Systems	4					
ECE 320	Linear Control Systems	4					
ECE 333	Digital Systems	4				Total credits required:	194
ECE 362	Principles of Design	3					
		<hr/>					
		15					

Area Electives

An area elective course is:

1. Any course bearing an ECE prefix at the 400 level or above.
2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Elective

1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

Notes

1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other R-HIT courses.
4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

Core Courses

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE160	Engineering Practice	2
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE230	Microcontrollers and Computer Architecture	4
ECE250	Electronic Device Modeling	4
ECE300	Signals & Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE333	Digital Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE371	Power & Energy Systems or Sustainable Energy Systems	4
ECE380	Discrete Time & Continuous Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

Second Major in Electrical Engineering

The ECE Department will not allow the following second major combinations:

1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Name	Credits
ECE 130	Introduction to Logic Design	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 230	Microcontrollers and Computer Architecture	4
ECE 250	Electronic Device Modeling	4
ECE 300	Signals & Systems	4
ECE 310	Communication Systems	4
ECE 320	Linear Control Systems	4
ECE 333	Digital Systems	4
ECE 340	Electromagnetic Fields	4
ECE 341	Electromagnetic Waves	4
ECE 351	Analog Electronics	4
ECE 370	Power & Energy Systems	4
or		
ECE 371	Sustainable Energy Systems	4
ECE 380	Discrete Time & Continuous Systems	4
Total		60

Area Minor in Electrical and Computer Engineering

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Fred Berry

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE205	Dynamical Systems	4
ECE300	Signals and Systems	4
ECE380	Discrete Time and Continuous Systems	4
ECE310	Communication Systems	4

Example Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits
ECE130	Introduction to logic Design	4
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

Enhanced Study in Communication Systems

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 410 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Signals and Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Dynamical Systems
- ECE300 Signals and Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

Enhanced Study in Power Systems

Power Certificate

Take all of the following courses:

- ECE 571 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

ECE 310 Communication Systems
OE 393 Fiber Optics and Applications
OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

ECE 380 Discrete Time & Continuous Systems
ECE 410 Communication Networks

- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

Electrical Physics Program Educational Objectives and Outcomes

The mission statement for the ECE (Electrical & Computer Engineering) Department: To provide students in ECE a rigorous learning experience that prepares them for professional careers.

EE Student Learning Outcomes: EE student learning outcomes are designed to instill in our graduates the skills appropriate to their professions and life-long learning. The EE program uses the term "student learning outcomes" to describe knowledge and skills at the time of graduation that are derived from the objectives.

Holistic Education: Electrical Engineering graduates shall be prepared to practice the profession of engineering using a systems perspective broad enough to encompass technological, economic, ethical, environmental, social, and human issues, shall have demonstrated a facility for independent learning, and shall be prepared for continued professional development.

- H1: Demonstrate a facility for independent learning
- H2: Be prepared for continued professional development
- H3: Effective communications skills
- H4: Contemporary Issues
- H5: Role of professional in global society

Technical Preparation: Electrical and Computer Engineering graduates shall demonstrate technical depth and breadth in their discipline.

- T1: General engineering science core plus a discipline-specific technical core
- T2: Effective use of contemporary tools of the engineering profession

Design & Professional Practice: Electrical Engineering graduates shall have participated in design experiences including a comprehensive, industrially-oriented design project, oral presentations, and written communications.

- D&P: Client sponsored team design experience

Electrical Engineering

Freshman Year				Sophomore Year			
Fall Term		Credit		Fall Term		Credit	
PH	111	Physics I.....	4	MA	211	Differential Equations	4
MA	111	Calculus I	5	CHEM	105	Engineering Chemistry I	4
CLSK	100	College and Life Skills	1	ECE	203	DC Circuits	4
				ECE	230	Microcontrollers and Computer Architecture	4

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

.....							
RH	131	Rhetoric & Composition				16	
or							
HSS		Elective	4	Winter Term			
ECE	160	Engineering Practice	2			Credit	
16				MA	212	Matrix Algebra and Systems of Differential Equations	4
						Math/Science Elective	4
Winter Term			Credit	ECE	204	AC Circuits	4
PH	112	Physics II.....	4	HSS		Elective	4
MA	112	Calculus II.....	5	16			
ECE	130	Introduction to Logic Design	4	Spring Term			
						Credit	
RH	131	Rhetoric & Composition or		MA	381	Introduction to Probability with Applications to Statistics	4
HSS		Elective	4	ECE	205	Dynamical Systems	4
17				ECE	250	Electronic Device Modeling	4
Spring Term			Credit	HSS		Elective	4
PH	113	Physics III	4	16			
MA	113	Calculus III.....	5				
HSS		Elective	4				
CSSE	120	Introduction to Software Development	4				
17							
Junior Year				Senior Year			
Fall Term				Fall Term			
						Credit	
ECE	300	Signals & Systems	4	ECE	460	Engineering Design I	3
ECE	370	Power & Energy Systems				Tech Elective	4
or						Area Elective	4
ECE	371	Sustainable Energy Systems	4	HSS		Elective	4
ECE	340	Electromagnetic Fields	4	15			
RH	330	Technical and Professional Communication	4				
16				Winter Term		Credit	
Winter Term			Credit	ECE	461	Engineering Design II	4
ECE	380	Discrete Time & Continuous Systems	4			Tech Elective	4
ECE	351	Analog Electronics	4			Area Elective	4
ECE	341	Electromagnetic Waves	4	HSS		Elective	4
				16			
				Spring Term		Credit	
16				ECE	462	Engineering Design III	2
						Free Elective	4
						Free Elective	4
						Area Elective	4

			HSS	Elective	4
Spring					
Term		Credit			18
ECE 310	Communications Systems	4			
ECE 320	Linear Control Systems	4			
ECE 333	Digital Systems	4			Total credits required: 194
ECE 362	Principles of Design	3			
		15			

Area Electives

An area elective course is:

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Elective

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

Notes

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, geology or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

Core Courses

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE160	Engineering Practice	2
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE230	Microcontrollers and Computer Architecture	4
ECE250	Electronic Device Modeling	4
ECE300	Signals & Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE333	Digital Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE371	Power & Energy Systems or Sustainable Energy Systems	4
ECE380	Discrete Time & Continuous Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

Second Major in Electrical Engineering

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Name	Credits
ECE 130	Introduction to Logic Design	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 230	Microcontrollers and Computer Architecture	4
ECE 250	Electronic Device Modeling	4
ECE 300	Signals & Systems	4
ECE 310	Communication Systems	4
ECE 320	Linear Control Systems	4
ECE 333	Digital Systems	4
ECE 340	Electromagnetic Fields	4
ECE 341	Electromagnetic Waves	4
ECE 351	Analog Electronics	4
ECE 370	Power & Energy Systems	4
or		
ECE 371	Sustainable Energy Systems	4
ECE 380	Discrete Time & Continuous Systems	4
Total		60

Area Minor in Electrical and Computer Engineering

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Fred Berry

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE205	Dynamical Systems	4
ECE300	Signals and Systems	4
ECE380	Discrete Time and Continuous Systems	4
ECE310	Communication Systems	4

Example Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits
ECE130	Introduction to logic Design	4
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

Enhanced Study in Communication Systems

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 410 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Signals and Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus) (intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Dynamical Systems
- ECE300 Signals and Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

Enhanced Study in Power Systems

Power Certificate

Take all of the following courses:

- ECE 571 Control of Power Systems, Pre: ECE 470

ECE 472 Power Systems II, Pre: ECE 470

- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113
- ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

ECE 310 Communication Systems

OE 393 Fiber Optics and Applications

OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

ECE 380 Discrete Time & Continuous Systems


ECE 410 Communication Networks

ECE 414 Wireless Systems

OE 360 Optical Materials and Opto-mechanics

OE 435 Biomedical Optics

OE 450 Laser Systems and Applications



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Institute of Technology**
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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Mathematics

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

PROGRAM GOALS AND OBJECTIVES

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

DEGREE REQUIREMENTS

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 211 Differential Equations	4 hrs.
MA 212 Matrix Algebra and Systems of Differential Equations	4 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core	12 hrs.
Three courses selected per the list below. Students completing the Continuous Applied	

Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- The project must involve work done by the student(s) to solve a problem presented by an external sponsor. The written project submission must be signed by the student's project advisor (who must be a member of the mathematics department) and two additional members (who are approved by the project advisor), and must be presented publicly to the department. The additional members of the committee may include

representatives of the sponsor.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team). The written submission must be signed by the student's thesis advisor (who must be a member of the mathematics department) and two additional faculty members (who are approved by the thesis advisor), and must be presented publicly to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement, one course must be RH330)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	2 hr.

Total hours required for graduation
195 hrs.

* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
AB 101 — Essential Biology (or higher-level AB course)	4 hrs.
CHEM 111 — General Chemistry I	4 hrs.
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
MA 332 - Introduction to Computational Science - may be taken instead instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework	
*** 200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.	24 hrs.
**** CLSK 100 — College and Life Skills	1 hr.
MA 200 Career Preparation	1 hr.

SUGGESTED SCHEDULE

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended basic chemistry course is CHEM 105 unless a student is taking a second major or minor requiring CHEM 111 or credit for CHEM 111 has already been received. If CHEM 111 is taken instead of CHEM 105 then the order of the basic science electives in the freshman and sophomore is the second science course listed. Two science courses are to be taken in the winter quarter of freshman year

MATHEMATICS

Freshman Year

Fall Term			Credit
MA	111	Calculus I	5
PH	111	Physics I	4
		or	
CHEM	111	General Chemistry I	4
RH	131	Rhetoric and Composition	
		or	4
HSS		Elective	
CLSK	100	College and Life Skills	1
CSSE	120	Introduction to Software Development	4
			16
			18

Winter Term			Credit
MA	112	Calculus II	5
PH	112	Physics II	4
		or	
PH	111	Physics I	4
CHEM	111	General Chemistry I	
		or	4
AB	101	Essential Biology (or higher level AB course)	
HSS		Elective	4
		or	
RH	131	Rhetoric Composition	4
			17

Spring Term			Credit
MA	113	Calculus III	5
PH	113	Physics III	4
		or	
PH	112	Physics II	4
MA	190	Contemporary Mathematics Problems	
HSS		Elective	4
			15

Junior Year

Fall Term			Credit
MA		Elective	4
		Technical Elective	4
		Technical Elective	4
HSS		Elective	4
		or	
RH	330	Technical and Professional Communication	4
			16

Sophomore Year

Fall Term			Credit
MA	211	Differential Equations	4
MA	275	Disc. & Comb. Algebra I	4
AB	101	Essential Biology (or higher level AB course)	4
		or	
PH	113	Physics III	4
*CSSE	220	Object-Oriented Software Development	
			16

Winter Term			Credit
MA	212	Matrix Algebra and Systems of Differential Equations	4
		Science Elective	4
		Technical Elective	4
HSS		Elective	4
**MA	200	Career Preparation	1
			17

Spring Term			Credit
MA	381	Introduction to Probability	4
MA	371	Linear Algebra I	4
		Technical Elective	4
HSS		Elective	4
			16

Senior Year

Fall Term			Credit
MA	491	Intro to Math Modeling (2 hours)	4
MA	492	Senior Project I (2 hours)	
		or	4
MA	496	Senior Thesis I (4 hours)	
		Free Elective	4
		Free Elective	4
HSS		HSS	4

Winter Term			Credit	16
MA	366	Functions of a Real Variable	4	
MA		Elective	4	Winter Term
		Technical Elective	4	Credit
		Elective		
HSS		or		MA 493 Senior Project II (2 hours)
			4	or 2
RH	330	Technical and Professional Communication		MA 497 Senior Thesis II (2 hours)
			16	MA Elective 4
				Free Elective 4
				Free Elective 4
				Free Elective 4
Spring Term			Credit	18
MA		Elective	4	
MA		Elective Technical Elective	4	Spring Term
			4	Credit
HSS		Elective		
		or	4	MA 494 Senior Project III (2 hours)
RH	330	Technical and Professional Communication		or 2
			16	MA 498 Senior Thesis III (2 hours)
				MA Elective 4
				Free Elective 4
				Free Elective 4
				14

Total credits required: 195

Notes:

*MA 332 - Introduction to Computational Science - may be taken instead of CSSE 220 but then MA 332 cannot be counted towards the 63 hours of mathematics coursework

**MA 200 - Career Preparation - may be taken in either the winter or spring quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- **Math Elective:** A course either required by the concentration or a true math elective.
- **Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- **Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- **Free Elective:** Any course.

Computational Science Major (CPLS) (Second Major Only)

Computational methods are widely employed in science and engineering for simulation, experimentation, analysis, and design. In many areas the use of high-performance computing is essential. The Computational Science major provides Rose-Hulman students with the opportunity to add to their primary major a second major that increases their knowledge and skill in applied scientific and engineering computation.

Requirements for a second major in Computational Science (71 credit hours)

The second major in Computational Science is open to all students. It requires 71 credit hours, including a 55 credit hour core and a 16 credit hour specialization. The courses used to satisfy the requirements in the

Advanced Core may not be counted toward any other major or minor. All Computational Science programs of study are subject to approval by the Chair of the Computational Science Steering Committee

I. Computational Science Core (55 credit hours)

Fundamentals (35 credit hours)

- MA 111, 112, 113 Calculus I, II, III
- MA 211 Differential Equations
- MA 212 Matrix Algebra and Systems of Differential Equations
- CSSE 120 (1) Introduction to Software Development, or any of BE 100, CE 110, CHE 110 (plus 2 cr.), ME 123
- CSSE 132 or ECE130 Introduction to Computer Systems, Introduction to Logic Design
- MA 332 (2) Introduction to Computational Science, or any of CE 310 (plus 2 cr.) CHE 310, ME 323(plus 2 Credits)

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any upper-level computational science course (see list below)

List of Advanced Electives

- BE 510 Biomedical Signal and Image Processing
- CHE 521 Advanced Chemical Engineering Computation
- CSSE 304 Programming Language Concepts
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- ECE 582/PH 537 Advanced Image Processing
- EMGT 526 Technology Forecasting
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 348 Continuous Optimization
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis
- MA 435 Finite Difference Methods
- MA 439 Mathematical Methods of Image Processing
- MA 444 Deterministic Models in Operations Research
- MA 446 Combinatorial Optimization
- MA 490 Mathematical Biology
- ME 422 Finite Element Methods for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 522 Advanced Finite Elements Analysis
- Other courses may be counted as advanced electives upon approval by the Chair of Computational Science.

II. Area of Concentration (16 credit hours): Each student must complete 16 credit hours in an area of concentration within Computational Science. Courses used to satisfy the core requirements may not be used to satisfy the area of concentration requirements.

Computational Methods

- MA 371 or MA 373 Linear Algebra I, Applied Linear Algebra for Engineers
- MA 433 Numerical Analysis
- Eight credit hours chosen from CSSE 304, CSSE/MA 473, MA 348, MA 386, MA 434, MA 435, MA439, MA 444, MA 446, MA 485, ME 422

Computational Mechanics

- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- ME 401 Foundations of Fluid Mechanics
- ME 427 Introduction to Computational Fluid Dynamics

- ME 522 Advanced Finite Element Analysis

Computational Signals and Image Processing

- ECE 380 Discrete-Time Signals and Systems
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- MA 439 Mathematical Methods of Image Processing

Computational Physics and Chemistry

- CHEM 361 Physical Chemistry I
- CHEM 362 Physical Chemistry II
- CHEM 363 Quantum Chemistry & Molecular Spectroscopy
- OE 570 Nanomedicine
- PH 540 Computer Physics

Computational Biomedics

- BE 482/MA 482 Bioengineering Statistics
- BE 535/OE 535 Biomedical Optics
- BE 541/ECE 597 Medical Imaging
- MA 490-01 Mathematical Biology 1
- MA 490-02 Mathematical Biology 2

AREA MINOR IN MATHEMATICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 211, MA 212
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA211 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

AREA MINOR IN COMPUTATIONAL SCIENCE

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA211, MA212
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS:Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization
- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are not allowed to count MA332 and MA342 for both the minor and the major.
- A student may not apply the four upper-division courses toward both this minor and a math or statistics minor.

AREA MINOR IN STATISTICS

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- **Globally required mathematics courses**
 - MA 111 Calculus I
 - MA 112 Calculus II
 - MA 113 Calculus III
 - MA 212 Differential Equations
- **Required Introductory Statistics/Probability Courses:**
 - MA 381 Introduction to Probability with Applications to Statistics,
 - One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is

taken before MA223/MA382 the student will be strongly recommended to take MA382.

• **Required Second Statistics Course**

One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics

• **Electives**

3 courses (12 credits) selected from the following list, at least two of which must be starred. Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.

- MA 385* Quality Methods
- MA 386* Statistical Programming
- MA 387* Statistical Methods in Six Sigma
- MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers
- MA 445 Stochastic Models in Operations Research
- MA 481* Mathematical Statistics
- MA 485* Regression and Time Series Analysis
- MA 487* Design of Experiments
- MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students
- Only MA111, MA112, MA113, MA212 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.



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Institute of Technology**
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News

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Mechanical Engineering

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Since mechanical engineering is a broad field of endeavor, the curriculum offers a strong technical elective program to allow each student to craft a broad educational experience and to develop the flexibility to pursue diverse career goals.

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Systems Design.

The strength of any department is its faculty. The mechanical engineering faculty are committed to providing a dynamic and innovative learning environment and to maintaining and increasing their technical competence in a rapidly changing world. Stereotypes notwithstanding, they understand that people are more important than things. Thus, they encourage each student to seek them out when he or she has academic problems or needs guidance in career planning.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 12 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission:

To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Vision:

To graduate the best baccalaureate mechanical engineers.

Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

1. an ability to apply knowledge of mathematics, science, and engineering
2. an ability to design and conduct experiments, as well as to analyze and interpret data
 1. Identify the problem and develop an appropriate experimental approach
 2. Select measurement techniques to collect appropriate data and justify that selection.
 3. Estimate experimental uncertainties.
 4. Collect and present data in an accurate and orderly way.
 5. Use appropriate statistical procedures to analyze and evaluate the information contained in a data set.
 6. Analyze the data and draw supportable conclusions from the result
3. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
 1. Understand the problem.
 2. Develop a design specification that addresses customer/client needs and constraints.
 3. Carry out a conceptual design by generating multiple solutions that address the requirements of the design specification.
 4. Evaluate the feasibility of the solutions.
 5. Choose an appropriate solution and justify that solution
 6. Carry out a conceptual-level design using appropriate design tools and methodologies.
 7. Test and refine the implementation until the product or process design specifications are met or exceeded.
 8. Document the finished product or process as appropriate for the discipline according to standard practice.
4. an ability to function on multi-disciplinary teams
 1. Demonstrate how you reached a decision as a team.
 2. Describe the team role you filled and how that contributed to the final project.
 3. Listen openly, actively, and critically.
5. an ability to identify, formulate, and solve engineering problems
 1. Inspect and define the problem.
 2. Identify the basic principles and concepts that apply to the situation.
 3. Build appropriate model(s).
 4. Solve the problem by choosing appropriate tools (analytical, experimental, and computational).
 5. Check a solution using appropriate criteria.
6. an understanding of professional and ethical responsibility
 1. Explain important ethical obligations associated with your discipline.
 2. Apply a systematic ethical framework to an ethical issue or situation in a disciplinary context.
7. an ability to communicate effectively
 1. Provide a substantive critique that includes recommendations for improvements.

2. Adapt technical information for a non-specialized audience.
3. Convey information effectively through visual media.
4. Present information visually using drawings, graphs and sketches.
5. Deliver oral presentations with clarity and professionalism.
8. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
 1. Engage in the arts (music, theater, art, dance, creative writing, etc.)
 2. Analyze patterns, dynamics, or values of human interaction in social or cultural systems.
 3. Analyze beliefs, backgrounds, cultures, or societies different from your own.
 4. interpret cultural artifacts and/or ideas in philosophy, the arts, or the sciences.
9. a recognition of the need for, and an ability to engage in life-long learning
 1. Students will describe how their current state of performance in an ability has already impacted or might in the future negatively impact their project or team.
 2. Students will describe steps they will follow to reach their desired performance level in the ability.
 3. Students will describe evidence that indicates that they have achieved their professional development goal.
 4. Students will describe the "most significant" professional development they achieved and explain its impacts.
 5. Students will explain what they have learned about the professional development process that will transfer into life after graduation.
10. a knowledge of contemporary issues
 1. Students will identify the problem.
 2. Students will describe the problem from different perspectives (At least two sides)
 3. Students will identify stakeholders and describe how stakeholders are affected
 4. Students will justify arguments logically.
 5. Students will reference sources appropriately.
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Area Minor*** in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

- ME 301 Thermodynamics II
- CHE 303 Chem. Engineering Thermodynamics
- ME 302 Heat Transfer
- CHE 320 Fundamentals of Heat and Mass Transfer

(3) Three of the thermal-fluids electives listed below.

- *Thermal Fluid Systems*
 - ME 407 Power Plants**
 - ME 408 Renewable Energy
 - ME 409 Air Conditioning*
 - ME 410 Internal Combustion Engines
 - ME 411 Propulsion Systems**
 - ME 426 Turbomachinery
- *Thermal Fluid Sciences*
 - ME 401 Foundation of Fluid Mechanics

- ME 402 Advanced Heat Transfer*
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics**
- ME 502 Topics in Heat Transfer*
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

**Requires one of the thermodynamics prerequisites from section 2 above.

* Requires one of the heat transfer prerequisites from section 2 above.

*** ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Students who complete recommended courses in an area of concentration may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the selected area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to take these course offerings without overload. Students may include special topics courses or new courses not yet listed in the catalog to the list of acceptable courses for a concentration with written permission from the mechanical engineering department head

Advanced Transportation Concentration

To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

- ECE/ME 497 Introduction to Model-Based System Design
- ECE/ME 497 Advanced Model Based-System Design

Elective Courses

- CHEM 470 Combustion Chemistry
- ECE 320 Linear Control Systems
or
ME 406 Control Systems
- ECE 420 Nonlinear Control Systems
or
ME 506 Advanced Control Systems
- ECE 370 Machines & Power
- ECE 410 Communication Networks
- ECE 452 Power Electronics
- ME 408 Renewable Energy
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 422 Finite Elements for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics
- ME 450 Combustion

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

- ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

- MA 336 Boundary Value Problems
- ME 405 Theoretical Aerodynamics
- ME 401 Foundation of Fluid Mechanics
- ME 411 Propulsion Systems
- ME 422 Intro to Finite Element Fundamentals
- ME 426 Turbomachinery
- ME 427 Introduction to Computational Fluid Dynamics
- ME 461 Aerospace Design
- ME 503 Viscous Flow
- ME 510 Gas Dynamics
- ME 512 Light Weight Structures
- ME 522 Advanced Finite Element Analysis
- PH 322 Celestial Mechanics

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 or CHE 450 Air Pollution (cross-listed class)
- CE 590 Climate Change Assessment
- CHE 490 Energy and Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power and Energy Systems
- ECE 371 Industrial Power Systems
- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 450 Combustion
- ME 501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma

Engineering Management List

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 520 Accounting for Technical Managers
- EMGT 521 Financial Management in a Technical Environment
- EMGT 522 Organizational Management
- EMGT 523 Marketing Issues in a Technical Environment 4
- EMGT 524 Production/Operations Management
- EMGT 526 Technology Management and Forecasting
- EMGT 527 Project Management
- EMGT 531 Economics for Technical Managers
- EMGT 532 Technical Entrepreneurship
- EMGT 533 Intercultural Communication
- EMGT 534 Management Science
- EMGT 535 Strategies for Organizational Change
- EMGT 586 Supply Chain Management
- EMGT 587 Systems Engineering
- EMGT 588 Quality Management I
- EMGT 589 Manufacturing Systems

Humanities, Social Sciences List

- GS 350 International Trade
- GS 351 International Finance
- IA 230 Fundamentals of Public Speaking
- SV 151 Principles of Economics
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- IA 352 Game Theory
- SV 303 Business and Engineering Ethics
- SV 304 Bioethics
- SV 352 Money & Banking
- SV 353 Industrial Organization
- SV 354 Environmental Economics
- SV 356 Corporate Finance
- EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

- EMGT 330 Introduction to Engineering Management
- EMGT 427 Project Management
- EMGT 588 Quality Management
- EMGT 589 Manufacturing Systems
- MA 385 Quality Methods
- ME 317 Design for Manufacturing
- ME 417 Advanced Materials Engineering
- ME 435 Robotics
- ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 401 Foundations of Fluid Mechanics
- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics
- ME 502 Topics in Heat Transfer
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the ****Thermal Fluid Systems****list and at least two courses are taken from the ****Thermal Fluid Sciences****list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

The mechanical engineering program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org

MECHANICAL ENIGNEERING PLAN OF STUDY

Freshman Year			Sophomore		
Fall Term			Year		
MA 111	Calculus I	Credit 5	Fall Term		Credit
PH 111	Physics I	4	MA 211	Differential Equations	4
CLSK 100	College & Life Skills	1	ES 201	Conservation &	4
EM 104	Graphical Communications	2		Accounting Principles	
RH 131	Rhetoric and Composition	4	ES 203	Electrical Systems	4
	split fall or winter with		HSS	Elective	4
HSS	Elective			Total	16
	Total	16	Winter Term		Credit
Winter Term			MA 212	Matrix Algebra and	4
MA 112	Calculus II	5		Systems	
PH 112	Physics II	4		of Differential Equations	
ME 123	Computer Applications I	4	ES 202	Fluid & Thermal Systems	3
RH 131	Rhetoric and Composition	4	ES 204	Mechanical Systems	3
	split fall or winter with		CHEM 111	General Chemistry I	4
HSS	Elective		HSS	Elective	4
	Total	17		Total	18
Spring Term			Spring Term		Credit
MA 113	Calculus III	5	MA 223	Statistics for Engineers	4
PH 113	Physics III	4	ES 205	Analysis & Design of	4
EM 103	Introduction to Design	2		Engineering Systems	
EM 121	Statics and Mechanics	4	CHEM 113	General Chemistry II	4
	of Materials I		HSS	Elective	4
	Total	15		Total	16

Junior			Senior Year		
Year			Fall Term		
Fall Term		Credit	ME 430	Mechatronic Systems	4
ME 301	Thermodynamics II	4		split fall or winter with	
EM 204	Statics and Mechanics	4	ME 421	M.E. Lab and *Tech Elective	(2+4)
	of Materials I		ME 406	Control Systems	4
ECE 207	Elements of Electrical Engrg II	4		or	
*Free	Elective	4	EM 406	Vibration Analysis	(4)
	Total	16	ME 480	Machine Component Design	4
Winter Term				split Jr. spring or Sr. fall with	
ME 317	Design for Manufacturing	(3) 3	ME 470	Engineering Design Proc & Method(3)	
ME 321	Measurement Systems	4	*Tech	Elective	(4) 4
	split winter or spring with			Total	(17) or 16
ME 323	Computer Applications II	(2)	Winter Term		Credit
Science	Elective	(4)	ME 471	Capstone Design I	(3) 3
ME 328	Materials Engineering	(4) 4	ME 421	M.E. Lab and *Tech Elective	2+4
RH 330	Technical Communications	(4)		split fall or winter with	
	split winter or spring with		ME 430	Mechatronic Systems	(4)
HSS	Elective	4	HSS	Elective	(4) 4
			*Free	Elective	(4) 4

Total		(17) or	Total		(15) or 17
		15	<i>Spring Term</i>		<i>Credit</i>
<i>Spring Term</i>		<i>Credit</i>	ME 472	Capstone Design II	3
ME 302	Heat Transfer	(4) 4	*Tech	Elective	4
ME 323	Computer Applications II	2	**Adv. Tech	Elective	4
Science	Elective	4	HSS	Elective	4
split winter or spring with			Total		15
ME 321	Measurement Systems	(4)	Total credits required:		194
ME 470	Engineering Design Proc & Method	3			
ME 480	split Jr. spring or Sr. fall with	(4)			
	Machine Component Design				
HSS	Elective	(4)			
split winter or spring with					
RH 330	Technical Communications	4			
Total		(16) or 17			

*24 credit hours. in electives composed of 16 cr. hrs. in technical electives, of which at least 4 cr. hrs. must be in advanced level courses and 8 cr. hrs. in free electives. (i.e. 12 cr. hrs. tech. electives, 4 cr. hrs. adv. tech elective, 8 cr. hrs. free electives)

** An **advanced technical elective** is designated with an * in the undergraduate bulletin ME and EM course description section or any 500 level course and above in BE, ChE, CE, CPE, EE, ME, OE or SE programs. A technical elective is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, geology, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. A **science elective** is any course in applied biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.



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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/phoe>

Optical Engineering Program Educational Objectives and Outcomes

Mission:

To provide a coherent foundation of physics for all students and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. In the engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision:

To cultivate a sense of responsibility, independence, and instill knowledge that allows the students to be fully

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

engaged in all disciplines, continuously improve the curriculum through assessment, and be engaged in professional development.

The educational objectives of the optical engineering program are to prepare students to:

General Educational Objectives

- 1. Exhibit strong skills in problem solving, leadership, teamwork, and communication.
- 2. Use these skills to contribute to their community and globally.
- 3. Make thoughtful, well-informed choices in their projects and career.
- 4. Demonstrate commitment to continuous education (life long learners) of themselves and of others.

Core Educational Objectives

- 5. Be effective multi-disciplinary optical engineers/researchers.
- 6. Be educated in the principles of optical science and engineering necessary to understand optical systems.
- 7. Be able to use optical engineering and engineering tools that will allow them to design, build, and test systems that will incorporate optics as an enabling technology.
- 8. Be able to communicate effectively in oral, written, and graphical forms as needed in a multidisciplinary team.
- 9. Be aware of the impact of their work in local and global environment, society, and human heritage.

By the time students graduate with an optical engineering degree from Rose-Hulman, they will demonstrate:

- **Knowledge of the Fundamentals:** An understanding of the fundamentals of science and engineering.
- **Interpreting Data:** Ability to interpret graphical, numerical, and textual data.
- **System Level Modeling:** Ability to model components and system optical engineering problems.
- **Experimentation:** Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.
- **Design:** Ability to design a product or process to satisfy client's needs subject to constraints.
- **Team Work and Deliverables:** Ability to work in multi-disciplinary teams, understand the effective team dynamics and be able to deliver a product.
- **Problem Solving:** Ability to apply relevant scientific and engineering principles to solve real world optical engineering problems.
- **Professional Practice and Ethics:** A sound understanding of what an optics professional is and have an awareness and understanding of professional ethics.
- **Communication:** Ability to communicate effectively in oral, written and visual forms.
- **Contemporary Issues, Non-technical Issues, Global Awareness:** An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- **Life Long Learning:** A facility for independent learning and continued professional development.

Optical Engineering

Freshman Year				Sophomore Year			
Fall Term		Credit		Fall Term		Credit	
MA	111	Calculus I	5	MA	223	Engineering Statistics	
PH	111	4			or	
CLSK	100	Physics	1	SL	151	Principles of	4
RH	131	I.....	4	PH	235	Economics.....	4
EM	104	College and Life Skills	2	MA	211	Many-Part	4
			PH	292	Physics.....	4
		Rhetoric and Composition				Differential Equations	
		
		Graph				Physical	
		Comm.....				Optics.....	
			16				16*
Winter				Winter			
Term		Credit		Term		Credit	

Total credits required: 194

*If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

Summary of Graduation Requirements for Optical Engineering

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects	Hours
Optics Coursework	46
Physics Coursework*	20
Freshmen Physics, Chemistry and Mathematics Coursework**	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous***	25
Total	194

Physics Classes		
Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4
PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes		
Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM105	Engineering Chemistry I	4
CHEM107	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes		
Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
EP 406	Semiconductor Devices and Fabrication	4
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
Total		25

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required Courses

Course	Hours	Course Description
OE 280	4	Paraxial Optics
PH 292	4	Physical Optics
OE 295	4	Optical Systems

Plus at least two* courses from one of the areas listed below:

Lens Design Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 480	4	Lens Design and Aberrations
OE 490	4	Directed Research (4 Credits Only)
Photonics/Electro-optics Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-optics and Applications
OE 490	4	Directed Research (4 credits only)
OE 493	4	Fundamentals of Optical Fiber Communications
Image Processing Area		
Course	Hours	Course Description
OE 415	4	Optical Engineering Design I
OE 490	4	Directed Research (4 Credits Only)
PH 437/ECE 480	4	Introduction to Image Processing
PH 537/ECE 582	4	Advanced Image Processing

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)
Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203*	4	DC Circuits
ECE 204*	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

*required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses


- ECE 310 Communication Systems

- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

Physics

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
		Credit			Credit
MA	111 Calculus I	5		Free	4
PH	111.....	4	PH	235 Elective†.....	4
CLSK	100 Physics I.....	1	MA	211 Many Particle Physics	4
RH	131		PH	292	4
	College and Life Skills			Differential Equations.....	
HSS	Rhetoric and Composition	4		Physical Optics.....	
EM	104 or	2			
	Elective.....				16
	Graphical Communications .				
		16			
Winter Term			Winter Term		
		Credit			Credit
PH	112 Physics II.....	4	PH	255 Fund. of Modern Physics...	4
MA		5	HSS	Elective.....	4
					4
			MA	Technical	
				212 Elective.....	4
				Matrix Algebra and Systems	

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

CHEM112 Calculus II.....	4		of Differential Equations	
	2-4			
105 Engineering Chemistry I.....				16
Computing Elective*.....				
	15 or 17			
Spring			Spring	
Term	Credit		Term	Credit
PH 113Physics III	4		PH 314 Theoretical Mechanics I....	4
MA 113Calculus III.....	5		HSS Elective.....	4
CHEM107Engineering Chemistry II	4		MA 371	4
HSS Elective			Linear Algebra I	4
or			Math	
RH 131Rhetoric and Composition	4		Elective†.....	
	17			16
Junior Year			Senior Year	
Fall			Fall	
Term	Credit		Term	Credit
HSS Elective.....	4		Math Elective†.....	4
PH 316Electric and Magnetic				4
Fields.....	4		Technical Elective†.....	4
Technical Elective†.....	4		HSS Elective.....	4
PH 405Semiconductor Materials				
and Applications.....	4		Free	
	16		Elective.....	
				16
Winter			Winter	
Term	Credit		Term	Credit
PH 317Electromagnetism	4		PH 425 Advanced Physics Lab II....	4
PH 401Intro Quantum Mechanics .	4		HSS Elective.....	4
HSS Elective.....	4			4
	4		Technical Elective†.....	4
Physics Elective†.....			Free	
	16		Elective†.....	
				16
Spring			Spring	
Term	Credit		Term	Credit
PH 325Advanced Physics Lab I.....	4			
HSS Elective.....	4		Technical Elective†.....	4
OE 450Laser Sys & App			OE 450 Laser Sys & App	
or			or	
Physics Elective†	4		Physics Elective.....	4
PH 327Thermodynamics & Statistical			Free	4
Mechanics.....	4		Elective.....	4
	16		Physics Elective†.....	
				16

Total credits required: 192

* Computing elective: 2 or 4 credit course on computing from the following course: AB 140, CHE 110, CSSE 120,

and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

Summary of Graduation Requirements for Physics Majors

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
- 4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
- 5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
- 6. Sixteen credits of free electives (cannot include ECE340).
- 7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
- 8. A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.
- 9. A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
EP 280	Introduction to Nano-engineering	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
OE 172	Optics and Technology	2
OE 280	Paraxial Optics	4
OE 360	Opto-mechanics and Optical Materials	4
OE 393	Fiber Optics and Applications	4
OE 480	Lens Design and Aberrations	4
OE 485	Electro-Optics and Applications	4
OE 495	Optical Metrology	4
PH 230	Intro to Astronomy and Astrophysics	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290, 490	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 322	Celestial Mechanics and Solar System Physics	4
PH 330	Material Failure	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
EP 406	Semiconductor Devices and Fabrication	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 437	Introduction to Image Processing	4

PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	(Arranged)
PH 470	Special Topics in Physics	(Arranged)
PH497,498,499	Senior Thesis+	(Arranged)

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year (the number of credits will be determined with the guidance of the faculty thesis advisor). Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

****Math and Chemistry Courses:**

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	
	Linear Algebra	4
MA 371	Engineering Chemistry I	4
CHEM 105	Engineering Chemistry II	4
CHEM 107		4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

Area Minor Programs

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus three of:

Course	Course Title	Hours
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	4
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4
PH 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowitz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4

PH 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty


Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar’s Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: <http://www.rose-hulman.edu/Class/phoe>



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

Graduates from the software engineering program will be prepared for many types of careers in software development. In the early phases of their careers, we expect Rose-Hulman software engineering graduates to be able to:

1. Develop complex systems (including analysis, design, construction, maintenance, quality assurance and project management) using the appropriate theory, principles, tools and processes.
2. Use appropriate computer science and mathematics principles in the development of software systems.
3. Solve problems in a team environment through effective use of written and oral communication skills.
4. Have knowledge of current issues presently involved in effectively performing duties as a software practitioner in an ethical and professional manner for the benefit of society.
5. Practice the lifelong learning needed in order to keep current as new issues emerge.
6. Develop software in at least one application domain.

Software Engineering Program Outcomes

By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex software systems
- Design and experiment with software prototypes
- Select and use software metrics
- Participate on software project teams involving students from both software engineering and other majors
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

SOFTWARE ENGINEERING

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
		Credit			Credit
CSSE	120Introduction to Software Development...		CHEM105Engineering Chemistry I.....		4
MA	111Calculus I	4	CSSE 232Computer Architecture I ...		4
PH	111Physics I.....	5	MA	Matrix Algebra and Systems	
RH	131Rhetoric & Composition	4		212of Differential Equations ...	4
CLSK	100College and Life Skills	4	MA	Discrete & Combinatorial	
		1	275	Algebra I.....	4
		<hr/>			<hr/>
		18			16
Winter			Winter		

Term		Credit	Term		Credit
CSSE	220Object-Oriented Software Development.....		CSSE 230Data Structures and Algorithm Analysis.....		
		4	CSSE 333Database Systems		4
	MA 112Calculus II.....	5	MA 375Discrete & Combinatorial Algebra II		4
	PH 112	4	Domain track course.....		4
	HSS Physics II.....	4			
	Elective.....	4			
		<hr/>			<hr/>
		17			16

Spring Term		Credit	Spring Term		Credit
ECE	130Introduction to Logic Design.....		CSSE 304Programming Lang. Con.....		
		4	CSSE 376Software Quality Assurance		4
MA	113Calculus III.....	5	MA Elective.....		4
HSS	Elective.....	4	RH 330Technical and Professional Communication		4
Science	Elective.....	4			
		<hr/>			<hr/>
		17			16

Junior Year Fall Term		Credit	Senior Year Fall Term		Credit
CSSE371Software Requirements & Specification			CSSE377Software Architecture and Design II		
CSSE372Software Project Management		4	CSSE497Senior Project I		4
MA 381Introduction to Probability with Statistical Applications		4	HSS Elective.....		4
Domain track course.....		4	Domain track course or free elective.....		4
		4			
		<hr/>			<hr/>
		16			16

Winter Term		Credit	Winter Term		Credit
CSSE332Operating Systems.....			CSSE498Senior Project II.....		
CSSE374Software Arch. and Des....		4	CSSE Elective.....		4
HSS Elective...		4	HSS		4
Domain track course.....		4	Free Elective.....		4
		4	Elective		
		<hr/>			<hr/>
		16			16

Spring Term		Credit	Spring Term		Credit
CSSE373Formal Methods in Specification and Design			CSSE499Senior Project III		
CSSE375Software Construction and Evolution		4	HSS Elective		4
HSS Elective.....		4	Free		4
Domain track course or free elective.....		4	Elective		4
		4			
		<hr/>			<hr/>
					12

Summary of graduation requirements for the software engineering major

To complete the major in software engineering a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE377, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE 130; PH111, PH112, CHEM105; RH 131, RH330; CLSK100.
2. One additional CSSE elective course except CSSE 325, CSSE 473, CSSE 474, and CSSE 479. In addition, use of CSSE 49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.
3. All of the courses in one of the following application domain tracks:

Biochemistry (4-5 courses, 16-20 credit hours)

- CHEM 107 Engineering Chemistry II (4)
- CHEM 230 Intro. to Organic Chem. & Biochemistry (4) or
- CHEM 251-252 Organic Chemistry I-II (4 each)
- CHEM 330 Biochemistry (4 hours)
- CHEM 363 Quantum Chem. & Molecular Spectroscopy (4)

Biomedical (3 courses, 12 credit hours)

- BE 310 Analysis of Physiological Systems I (4)
- BE 320 Analysis of Physiological Systems II (4)
- BE 360 Biomaterials (4)

Commercial Applications (3 courses, 12 credit hours)

- SV 151 Principles of Economics (4)
- SV 350 Managerial Accounting (4)
- SV 351 Managerial Economics (4) or
- IA 350 Microeconomics (4) or
- IA 453 The Entrepreneur (4)

Economic Computing (4 courses, 16 credit hours)

- SV 151 Principles of Economics
- IA 350 Intermediate Microeconomics
- IA 351 Intermediate Macroeconomics
- Plus any additional economics course

Electrical Engineering (4 courses, 16 credit hours)

- ES 203 Electrical Systems (4)
- MA 222 Differential Equations II (4)
- ECE 200 Circuits and Systems (4)
- ECE 300 Signals and Systems (4)

Ethics and Law of Business (3 courses, 12 credit hours)

- IA 101 Introduction to Philosophy (4)
- EMGTxxx Business Law (4)
- SV 303 Business and Engineering Ethics (4)

Engineering Management (3 courses, 12 credit hours)

- SV 151 Principles of Economics (4)

- SV 356 Corporate Finance (4)
- EMGT 526 Technology Management and Forecasting (4)

Fundamentals of Engineering (6 courses, 22 credit hours)

- MA 222 Differential Equations II (4)
- ES 201 Conservation and Accounting (4)
- ES 202 Fluid and Thermal Systems (3)
- ES 203 Electrical Systems (4)
- ES 204 Mechanical Systems (3)
- ES 205 Analysis and Design of Engineering Systems (4)

Game Development Domain Track (6 courses, 24 credit hours)

- CSSE 351 – Computer Graphics (4)
- CSSE 451 – Advanced Computer Graphics (4)
- CSSE 490 or CSSE491 (Special Topics/Directed Studies) – Computer Game Design (4)
- MA 323 – Geometric Modeling (4)
- IA 334 – Creative Writing (4)
- SV 231 – Introduction to Short Fiction (4)

Genetics (4 courses, 16 credit hours)

- AB 110 Biology – Cell Structure and Function
- AB 210 Mendelian and Molecular Genetics
- AB 411 Genetic Engineering
- AB 431 Genomics and Proteomics

Geography (3 courses, 12 credit hours)

- SV 191 - Cultural Geography (4)
- GS 491 - Geography of Europe (4)
- GS 492 - Geography of Africa and Southwest Asia (4)

International and Diversity Issues (4 courses, 16 credit hours)

- IA 311 Issues in German Culture
- GS 384 Japanese Society
- EMGT 533 Intercultural Communication
- SV 373 Gender Issues
- and some type of international experience related to the domain track (requires CSSE department head approval)

International Business and Economics (4 courses, 16 credit hours)

- SV 151 Principles of Economics (4 hours)
- IA 351 Intermediate Macroeconomics (4 hours)
- GS 350, International Trade and Globalization
- GS 351 International Finance (4 hours)

Mechanical Robotics Domain Track (5 courses, 19 credit hours)

- ME430 Mechatronics
- ES201 Cons & Acct Princ
- ES204 Mechanical Systems
- ME303 Kinematics
- ME435 Robotics Engineering

Music Comprehension (4 courses, 14 credit hours)

- SV 244 Music History: Medieval, Renaissance, Baroque
- IA 246 Music Theory I
- MUS 113 Music Skills I (Indiana State University course)
- MUS 150 Introduction to Musical Traditions I (Indiana State University course)

Physical Modeling (4 courses, 16 credit hours)

- MA 222 Differential Equations and Matrix Algebra II (4)

- MA 323 Geometric Modeling (4)
- MA 371 Linear Algebra (4)
- MA 433 Numerical Analysis (4)

Robotics Domain Track (5 courses, 20 credit hours)

- ME430 Mechatronics
 - ECE203 DC Circuits
 - ECE204 AC Circuits
 - ECE205 Dynamical Systems and ECE497 Mobile Robotics
- Or
- CSSE413 Artificial Intelligence and ME435 Robotics Engineering

Scientific Computing (4 courses, 16 credit hours)

- MA 222 Differential Equations and Matrix Algebra II (4)
- MA 373 Applied Linear Algebra for Engineers (4)
- MA 433 Numerical Analysis (4)
- MA 439 Mathematical Methods of Image Processing (4)

Statistical Applications (3 courses, 12 credit hours)

- MA 223 Engineering Statistics I
- or
- MA 382 Introduction to Statistics with Probability
- MA 383 Engineering Statistics II
 - MA 386 Statistical Programming

World Political Studies (3 courses, 12 credit hours, plus one additional requirement)

- GS 366 The European Union (4)
 - GS 163 International Relations (4)
 - GS 363 European Politics and Government (4)
- and some type of international experience related to the domain track. (requires CSSE Department Head approval)

World Security and Economics Domain Track (6 courses, 24 credit hours)

- GS 163 International Relations
- GS 361 Politics of the Global Economy
- SV 151 Principles of Economics
- CSSE 432 Computer Networks
- CSSE 442 Computer Security
- MA 479 Cryptography

The application domain track should be selected in consultation with the student's academic advisor, and filed with that advisor by the beginning of the junior year. Exceptions to application domain track requirements require department head approval.

4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
5. Four credits of science electives, which can be any CHEM, GEOL, PH, or AB courses not already required for the software engineering major.
6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

- CSSE 120, *Introduction to Software Development*
- CSSE 220, *Object-Oriented Software Development*
- CSSE 230, *Data Structures and Algorithm Analysis*
- CSSE 371, *Software Requirements and Specification*
- CSSE 374, *Software Architecture and Design*

Two additional courses in software engineering chosen from CSSE 372, 373, 375-377.



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation, contact Air Force ROTC for more details.

Scholarships

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

Profession of Arms - Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.

Communications Skills - Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies - Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies - Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

General Military Courses

Freshman Year

	Credit
AS 101 Found. of the US Air Force I	1
AS 101LLeadership Laboratory	0
AS 102 Found. of the US Air Force II	1
AS 102LLeadership Laboratory	0
AS 103 Found. of the US Air Force III	1
AS 103LLeadership Laboratory	0

Professional Officer Courses

Junior Year

	Credit
AS 301 Air Force Lead. Studies I	4
AS 301LLeadership Laboratory	0
AS 302 Air Force Lead. Studies II	4
AS 302LLeadership Laboratory	0
AS 303 Air Force Lead. Studies III	4
AS 303LLeadership Laboratory	0

Sophomore Year

	Credit
AS 201 Evol. of Air & Space Power I	2
AS 201LLeadership Laboratory	0
AS 202 Evol. of Air & Space Power II	2
AS 202LLeadership Laboratory	0
AS 203 Evol. of Air & Space Power III	2
AS 203LLeadership Laboratory	0


Senior Year

	Credit
AS 401 Nat.Sec.Aff./Prep. for Active	4
AS 401LDuty I	0
AS 402 Leadership Laboratory	4
AS 402LNat.Sec.Aff./Prep. for Active	0
AS 403 Duty II	4
AS 403LLeadership Laboratory	0
Nat.Sec.Aff./Prep.for Active DutyIII Leadership Laboratory	

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.

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Areas of Study

[Global Studies](#)

[Society and Values](#)

Majors

[International Studies \(second major only\)](#)

[German Technical Translation Certification](#)

Minors

[Anthropology](#)

[Art](#)

[East Asian Studies](#)

[Economics](#)

[European Studies](#)

[Geography](#)

[German](#)

[History](#)

[Ideas and Arts](#)

[Modern Languages](#)

[Economics](#)

[Japanese](#)

[Language and Literature](#)

[Latin American Studies](#)

[Music](#)

[Political Science](#)

[Philosophy and Religion](#)

[Psychology](#)

[Spanish](#)

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

Professors: Bremmer, Brophy, Carlson, Carvill, Casey, Christ, Clark, Dyer, Garcia, Gardner, Heeter, Hirotani, House, Kim, Kukral, Kuo, Letsinger, Livingston, Luegenbiehl, Martland, Michel, Minster, Smith, Taylor, Turner, Watt, and Williams.

Mission Statement

To enable our students to become creative, sophisticated thinkers, active citizens, and effective leaders in the global community, the department contributes to a broad liberal education, introducing students to a wide array of disciplines and traditions in the humanities and social sciences. In doing so, it provides learning experiences that, in addition to their intrinsic value, enrich a scientific and technical education.

Educational Objectives

Within the context of a liberal education, the department fosters in its students the desire and the ability to:

• **Think critically**, forming cogent, informed opinions, defining and solving problems with an awareness that societal processes are complex and interactive;

• **Communicate effectively** to diverse audiences, including those from other cultures and communities;

• **Succeed in a global context** by understanding and adapting to diverse cultures, alternative points of view, and the challenges of globalization;

• **Exhibit ethical and responsible leadership** as individuals, citizens, and professionals, committed to lifelong learning and achievement.

Disciplines

The HUMANITIES study what it means to be human within a contemporary or historical context. These disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

https://www.rose-hulman.edu/course-catalog/course-catalog-2010-2011/course-descriptions/humanities-and-social-sciences.aspx#intl-studies[1/20/2017 1:11:34 PM]

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art	Anthropology
English and Literature	Economics
Foreign Languages (German, Japanese, and Spanish)	Geography
History	Political Science
Music	Psychology
Philosophy and Religion	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

Global Studies (GS prefix): Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

Ideas and Arts (IA prefix): Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

Society and Values (SV prefix): Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communications are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communications is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

Course Levels in the Humanities and Social Sciences

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general **lower level courses (100 and 200 level)** tend to be broad surveys of particular subject areas within disciplines. **Upper level courses (300 and 400 level)** are often more focused in terms of subject matter and may go into greater depth of content.

Graduation Requirements

1. General

All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the

course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted RH transfer credit, but are not exempted from RH 131.

Exemption: An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. **Any HSS course may be substituted for RH 131 for exempted students.**

1. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.
2. Has received grades of B or higher in all high school English courses.

3. Technical and Professional Communication

Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted RH transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

Students who elect to take a foreign language should note the following special requirements.

1. HSS credit will not be awarded for an introductory-level language class (GE111, JP111, or SP111) until the student takes and passes the following course in the language sequence.
2. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three **thematic categories** as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each **thematic category** in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
3. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
4. Students may not earn foreign language credit in their native languages.

Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

6. Minors

Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

Help with Requirements

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, or Spanish, by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

<i>Minor</i>	<i>Advisor</i>
Anthropology	Scott Clark
Art	Steve Letsinger
East Asian Studies	Huei-Ying Kuo
Economics	Dale S. Bremmer

European Studies
German
Geography
History
Japanese
Language and Literature
Music
Latin American Studies
Philosophy and Religion
Political Science
Psychology
Spanish

Kevin Christ
Jong Hun Kim
Andreas Michel
Heidemarie Heeter
Michael A. Kukral
Samuel Martland
Maki Hirotani
Caroline Carvill
Gary Turner
Gustavo Garcia
Heinz Luegenbiehl
Terrence Casey
Patrick D. Brophy
John Gardner

Courses Offered

Global Studies – Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Introduction to East Asian History 4R-OL-4C

Examine the changing political-economic and cultural orders in the East Asian region (including China, Japan, and Korea) from imperial to modern era.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Asian Religions and Philosophy 4R-OL-4C

Focuses on the thought systems of India, China, and Japan. Discusses Hinduism, Buddhism, Confucianism, Taoism, and Shinto.

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History 4R-OL-4C

Explores the history and interaction of major world regions, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction’s humanistic usefulness in examining human values from an “extra-species, extra-terrestrial” perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 285 Humans and Culture 4R-OL-4C

Examines human adaptation and diversity; language and its use; the development and variety of economic, political, religious, family gender and expressive institutions.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis

on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS 324 Gender and Work in China 4R-OL-4C

Examine Chinese women's economic roles against the background of modern world history and China's transformation from 1600 to 2000.

GS 327 Modern China 4R-OL-4C

Examine the divergent responses to western challenges among the Chinese intellectuals, women, and urban bourgeoisie between the nineteenth to the first half of the twentieth centuries.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 350 International Trade and Globalization 4R-OL-4C Pre: SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Pre: SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Pre: SV 151

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 363 European Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of selected European political systems.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Contemporary Japan (Field trip to Japan) 4R-OL-4C

Examine contemporary Japan through the lectures, reading, and discussions during the course. Explorer the culture through the field trip to Japan.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 384 Japanese Society 4R-OL-4C

Examines the context within which individual Japanese live and work in contemporary Japanese society. Considers the “traditional” roots of Japan, the impact of industrialization, and current trends. Emphasizes the change and continuity in Japanese life, including the family and marriage, rural and urban lifestyles, education, and the organization of management and labor.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

Ideas and Arts -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R-OL-4C

Introduces the student to the methods and subject matter of philosophy through a selective consideration of fundamental philosophical problems such as the nature of reality, the existence of God, the criteria of knowing, and the basis of morality.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Jane Austen and the Rhetoric of Fiction 4R-OL-4C

Provides a guide to reading, appreciating, and analyzing Jane Austen's major novels. Analyzes a variety of film adaptations, comparing them to the novels in their rhetorical effects.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 4R-OL-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Concepts 4R-OL-4C

Teaches basic techniques of music notation and analysis of melody, harmony, rhythm, form, and style. Includes a comprehensive Analysis Project.

IA 302 Philosophy of Religion 4R-OL-4C

Examines the basic philosophical problems found in religion. Deals specifically with the nature of religion, the nature and existence of God, religious language, and the religious life.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 330 Documentary Film 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 346 Music Theory II: Applications 4R-OL-4C Pre: IA246 or consent of instructor

Applies notational and analytical techniques to arranging/composing tasks, using music notation software.

IA 348 Music Performance 1R-OL-1R Pre: Consent of Instructor

Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C Pre: SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C Pre: SV 151

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Pre: SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C Pre: SV 151

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 388 Chinese Nationalism 4R-OL-4C

Examine issues and debates surrounding the discussion on Chinese nationalism.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Pre: SV 151

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Pre: SV 151

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 463 Seminar on America's Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

IA 471 Literature of Madness 4R-OL-4C

Analyzes the literary, biographical, and scientific relationships between artistic and manic-depressed temperaments. Examines how "great wits and madness" relate.

Society and Values - Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres' conventions, traditions, and sociohistorical contexts.

SV 151 Principles of Economics 4R-OL-4C

Includes both microeconomics and macroeconomics. Analyzes market behavior. Considers production and pricing decisions under alternative industrial structures. Examines the determinants of economic growth, unemployment and inflation, including fiscal and monetary policy.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

Surveys learning, motivation, personality, intelligence, abnormal behavior, social behavior, perception, emotion, and psychobiology. Stresses objective analysis of behavior and provides a foundation for advanced courses.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 200 Career Preparation 1R-OL-1C W,S

This course is for economics majors, to be taken in the second or third year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resume preparation. This course is cross-listed with CHEM200, PH200 and MA200.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 226 The West in the East 4R-OL-4C

Analyze how the changing images of the West in China reflect China's changing status in the global economy.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV 244 Music History: Medieval, Renaissance, Baroque 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 245 Music History: Classical, Romantic, Modern 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 272 Experimental Psychology 4R-OL-4C

Emphasizes experimental analysis of perception, motivation, learning, and personality. Programmed and independent experiments are performed. Laboratory periods are arranged.

SV 288 Introduction to Sociology 4R-OL-4C

Examine the social and historical construction of our personal identity based on race, class, and gender as well as how social and global inequality is associated with these categories.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R-OL-4C

Examines the ethical issues faced by professional engineers in the global corporate context. Deals with such topics as codes of ethics, professional autonomy, employer authority, and whistle blowing.

SV 304 Bioethics 4R-OL-4C

Introduces students to basic issues in bioethics such as physician-patient relationships, the conduct of research, cross-cultural concerns, and codes of ethics.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 326 Overseas Chinese 4R-OL-4C

Examine theories about trading diasporas, the construction of ethnic others in nationalist discourses as well as historiographies on Chinese overseas migration from early modern to contemporary period.

SV 328 Comparative Business History 4R-OL-4C

Explore how culture matters to business organizations and the notion of entrepreneurship.

SV 332 Gender, Work, and Popular Culture 4R-OL-4C

Examines popular culture representations of masculinity and femininity in the workplace. Employs an interdisciplinary cultural studies approach for analyzing gendered representations of work and how they intersect with topics such as technology, race, and class.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 350 Managerial Accounting 4R-OL-4C Pre: SV 151

Covers accounting concepts and procedures for preparation of financial reporting. Emphasizes use of accounting as a tool for management control and decision making.

SV 351 Managerial Economics 4R-OL-4C Pre: SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. In addition to SL 151, students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Pre: SV 151

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Pre: SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Pre: SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Pre: SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Pre: SV 151

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Pre: SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 373 Gender Issues 4R-OL-4C

Examines male-female differences in behavior, personality, emotion, and cognition. Examines how men and women differ as they pursue the goals of life and the degree to which these differences are innate or learned.

SV 375 Personality Theories 4R-OL-4C

Presents an organized summary of major contemporary theories of personality. Compares and contrasts theories of human behavior. Analyzes the degree that behavior is purposive, unconscious, instinctive, learned, modifiable, and predictable.

SV 382 Anthropology of Religion 4R-OL-4C

Examines various concepts and practices pertaining to the supernatural, focusing primarily on indigenous religions around the world. Discusses the relationships of religious beliefs, values, and practices with social organization, economic behavior, subsistence systems, and technology

SV 385 Archaeology & Prehistory 4R-OL-4C

Examines the human past through the analysis of cultural artifacts: the course focuses on the methods and techniques of archaeology and the study of the major cultural and social transformations from foraging to agricultural and complex civilizations.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and ongoing evolution: examines the evidence of the fossil record and genes, compares human behavior with other primates, considers physical basis for behaviors, and the extent and causes of human physical diversity..

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C Pre: SV 151

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

Communication

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis of texts and images, research methods, and the conventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Pre: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

Special Topics and Directed Study

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX496 Seminar for HSS Senior Project 2R-OL-2C F Pre: Economics or International Studies major and Junior or Senior standing, or permission of instructor

Reviews methodologies employed in Economics and/or International Studies, and directs students toward

approval of a senior project proposal. Required of all Economics and International Studies majors and double majors.

XX497 Directed Study for HSS Senior Project 2R-OL-2C Arranged Pre: XX496 W,S

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. Required of all Economics and International Studies majors and double majors.

Modern Languages

Note: Students may not earn foreign language credit in their native tongue

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Pre: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Pre: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F Pre: GE 213

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Pre: GE 311

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Pre: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C Summer Pre: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Pre: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W Pre: GE 411

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany S Pre: GE 412

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-XL-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

HSS Majors

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning Outcomes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 1. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 2. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 3. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 1. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 2. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 1. Assemble and evaluate resources for research in international studies.
 2. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA233	<i>World Literature</i>
GS163	<i>International Relations</i>
GS285	<i>Humans and Culture</i>
GS291	<i>World Geography</i>
SV151	<i>Principles of Economics</i>
GS223	<i>World History</i>

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

1. *International Political Economy*: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose *at least* three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General list

IA353	<i>History of Economic Thought</i>
GS322	<i>Industrial Revolution in a Global Context</i>
GS350	<i>International Trade and Globalization</i>
GS351	<i>International Finance</i>
GS352	<i>Economic Growth and Development</i>
GS361	<i>Politics of the Global Economy</i>
SV328	<i>Comparative Business History</i>
SV354	<i>Environmental Economics</i>

Regional list

GS128	<i>Introduction to East Asia</i>
GS161	<i>Comparative Politics</i>
GS222	<i>Modern Latin America</i>
GS366	<i>European Union</i>
GS363	<i>European Politics and Government</i>
GS399	<i>Geography of the Middle East</i>
GS492	<i>Geography of Africa</i>

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

1. *Comparative Cultures*: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322	<i>Industrial Revolution in Global Context</i>
GS333	<i>Travel in World Literature</i>
GS334	<i>Global Novel in the 20th Century</i>
GS432	<i>Literature of the Global Economy</i>
GS462	<i>Postcolonial Literature</i>
SV191	<i>Cultural Geography</i>
SV201	<i>Religion and Ecology</i>
SV226	<i>The West in the East</i>
SV382	<i>Anthropology of Religion</i>

Regional list (including but not limited to the following courses)

IA311	<i>Topics in German Culture I</i>
GS128	<i>Introduction to East Asia</i>
GS207	<i>Asian Religions and Philosophy</i>
GS222	<i>Modern Latin America</i>
GS313	<i>Contemporary Spain</i>

GS327	<i>Modern China</i>
GS335	<i>Arabic Literature</i>
GS379	<i>Japanese Culture</i>
GS391	<i>Contemporary Europe</i>
GS442	<i>Art History: Renaissance to Modern</i>
GS492	<i>Geography of Africa</i>

3. *Individualized Major*: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS Minors

Minor in Anthropology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

1. Five courses in Anthropology.

- a. The following three courses are required:

- **GS 285 Humans & Culture**
- **SV 385 Archaeology & Prehistory**
- **SV 386 Human Evolution**

2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.

3. Substitutions may be made with the approval of the Minor Advisor

Courses

- **GS 384 Japanese Society**
- **SV 382 Anthropology of Religion**
- **XX 399 Special Topics**
- **XX 499 Directed Study**

Minor in Art

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

1. Five Courses in Art:

- a. The following three courses are required:

- **IA142 Drawing**
- **IA148 Beginning Photography**
- **SV242 Visual Arts in Civilization**

2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.

3. Substitutions may be made with the approval of the Minor Advisor

Courses

- **GS 442 Art History: Renaissance to Modern**
- **IA 142 Drawing**
- **IA 148 Beginning Photography**
- **IA 244 Design and Color**
- **SV 242 Visual Arts in Civilization**

Minor in East Asian Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - **GS 128 Introduction to East Asian History**
 - **GS 207 Asian Religions and Philosophy**
 - **GS 324 Gender and Work in China**
 - **GS 327 Modern China**
 - **GS 384 Japanese Society**
 - **SV 226 The West in the East**
 - **SV 326 Overseas Chinese**
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Economics

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 1. **Principles of Economics (SV 151);**
 2. **Intermediate Microeconomics (IA 350) or Intermediate Macroeconomics (IA 351);**
 3. Three additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- **GS 350 International Trade and Globalization**
- **GS 351 International Finance**
- **GS 352 Economic Growth and Development**
- **IA 350 Intermediate Microeconomics**
- **IA 351 Intermediate Macroeconomics**
- **IA 352 Game Theory**
- **IA 353 History of Economic Thought**
- **IA 450 Mathematical Economics**
- **IA 453 The Entrepreneur**
- **SV 151 Principles of Economics**
- **SV 350 Managerial Accounting**
- **SV 351 Managerial Economics**
- **SV 352 Money and Banking**
- **SV 353 Industrial Organization**
- **SV 354 Environmental Economics**
- **SV 355 Health Economics**
- **SV 356 Corporate Finance**

SV 357 Labor Economics

- **SV 450 Econometrics**
- **XX 399 Special Topics**
- XX 499 Directed Study**

Minor in European Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)

2. Four courses selected from the following:

- **GS 313 Contemporary Spain**
- **GS 337 Shakespeare's Europe**
- **GS 363 European Politics and Government**
- **GS 366 The European Union**
- **GS 431 Literary London**
- **GS 469 Contemporary British Fiction and Film**
- **GS 491 Geography of Europe**
- **IA 311 Topics in German Culture I**
- **IA 337 European Romanticism**
- **SV 222 Western Civilization to 1500**
SV 223 Western Civilization from 1500 to the Present
- **SV 291 Medieval Europe**
- **SV 413 Contemporary Germany**
- **XX 399 Special Topics**
- XX 499 Directed Study**

3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.

4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Geography

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- **GS 191 Geography of Middle East**
- **GS 222 Modern Latin America**
- **GS 291 World Geography**
- **GS 327 Modern China**
- **GS 391 Contemporary Europe**
- **GS 491 Geography of Europe**
- **GS 492 Geography of Africa**
- **SV 191 Cultural Geography**
- **SV 291 Medieval Europe**
- **XX 399 Special Topics**
- XX 499 Directed Study**

Minor in History

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- **GS 128 Introduction to East Asian History**
- **GS 221 Colonial Latin America**
- **GS 223 World History**
- **GS 222 Modern Latin America**
- **GS 324 Gender and Work in China**
- **GS 327 Modern China**
- **GS 422 Industrial Revolution in Global Context**
- **IA 388 Chinese Nationalism**
- **SV 222 Western Civilization to 1500**
- **SV 223 Western Civilization since 1500**
- **SV 226 The West in the East**
- **SV 322 Disasters and Modern Society since 1700**
- **SV 326 Overseas Chinese**
- **SV 328 Comparative Business History**
- **SV 329 Cities in Latin American History**
- **XX 399 Special Topics**
XX 499 Directed Readings

Minor in Language and Literature

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and HS330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- **GS 237 Science Fiction**
- **GS 334 Travel in World Literature**
- **GS 335 The Global Novel in the Twentieth Century**
- **GS 336 Literature of War**
- **GS 337 Shakespeare's Europe**
- **GS 338 Contemporary Arabic Literature in Translation**
- **GS 412 Topics in German Culture II**
- **GS 431 Literary London**
- **GS 432 Literature and Film of the Global Economy**
- **GS 462 Postcolonial Literature**
- **GS 469 Contemporary British Fiction and Film**
- **IA 230 Fundamentals of Public Speaking**
- **IA 231 Introduction to Poetry**
- **IA 232 African American Music in American Literature**
- **IA 233 World Literature**
- **IA 234 Major American Writers**
- **IA 236 Jane Austen and the Rhetoric of Fiction**
- **IA 237 Introduction to Drama**
- **IA 238 African American Literature**
- **IA 239 Rhetoric of Science**
- **IA 240 Introduction to Shakespeare**
- **IA 241 Introduction to Film Studies**
- **IA 330 Documentary Film**
- **IA 331 American Modernism**
- **IA 333 Representations and Redefinitions of Reality**
- **IA 334 Creative Writing**
- **IA 335 Bible as Literature**
- **IA 336 Mystery & Horror Literature**

- **IA 337 European Romanticism**
- **IA 339 Rebellion in American Literature**
- **IA 431 History of the American Novel**
- **IA 436 Reinterpretations of Literary Themes**
- **SV 134 Popular Literature**
- **SV 231 Introduction to Short Fiction**
- **SV 232 Introduction to Non-Fiction**
- **SV 233 Survey of American Literature**
- **SV 332 Masculinity and Work in Fiction and Film**
- **SV 334 Utopian Thought and Literature**
- **SV 336 Contemporary American Fiction**
- **SV 337 20th century American Novel**
- **SV 339 Literature and the Environment**
- **SV 234 The American Dream**
- **XX 399 Special Topics**
- **XX 499 Directed Study**

Minor in Latin American Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - **GS 221 Colonial Latin America**
 - **GS 222 Modern Latin America**
 - **GS 323 The Andean Countries of South America**
 - **GS 313 Contemporary Spain**
 - **IA 332 Don Quixote**
 - **SV 329 Cities in Latin American History**
 - **SV 338 Latin American Fiction: The Boom and Beyond**
 - **XX 399 Special Topics**
 - **XX 499 Directed Topics**
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Modern Languages (German, Japanese, and Spanish)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413 Japanese Language and Culture X/XI/XII

XX 399 Special Topics

XX 499 Directed Study

NOTES:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.

Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

Minor in Music

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. A minimum of 40 credits must be earned to obtain the minor. 36 of these credits must be in HSS courses. The remaining four (4) credits may be in an approved course from outside the HSS Department.
2. The following four courses are required:
 - **SV244 Music History: Medieval, Renaissance, Baroque**
 - **SV245 Music History: Classical, Romantic, Modern**
 - **IA246 Music Theory I: Concepts**
 - **IA346 Music Theory II: Applications**
3. To fulfill the fifth course requirement for the Area Minor in Music, the candidate may choose ONE of the following options:
 1. **A course from outside the HSS Department**, approved by the Minor Advisor, such as:
 - ECE481 Electronic Music Synthesis
 - PH404 Acoustics
 - PH460 Directed Study (music-related)
 1. **IA 499: Directed Study in Music**. Pre-requisite: consent of the Minor Advisor.
 2. **IA 348: Music Performance**. Pre-requisite: consent of the Minor Advisor.
 3. Four (4) credits of Satisfactory participation in one or more of the formal Performing Groups (Concert Band, Jazz Ensemble, String Ensemble, and Chorus) are required. Performance credit may not be transferred from another college. One academic term of satisfactory participation earns one credit. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for “satisfactory participation” will be provided to the candidate by the Minor Advisor.

Minor in Philosophy and Religion

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy and Religion has the following requirements:

1. Five courses in Philosophy and Religion, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- **GS 207 Asian Religions and Philosophy**
- **IA 101 Introduction to Philosophy**
- **IA 302 Philosophy of Religion**
- **IA 335 Bible as Literature**
- **SV201 Religion and Ecology**
- **SV 303 Business and Engineering Ethics**

- **SV 304 Bioethics**
- **SV 382 Anthropology of Religion**
- **XX 399 Special Topics**
- **XX 499 Directed Study**

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- **GS 161 Comparative Politics**
- **GS 163 International Relations**
- **GS 361 Politics of the Global Economy**
- **GS 366 The European Union**
- **GS 363 European Politics and Government**
- **SV 166 American Politics and Government**
- **SV 369 British Politics and Government**
- **SV 463 Seminar on America's Future**
- **XX 399 Special Topics**
- **XX 499 Directed Study**

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Five courses in Psychology, distributed as follows:
 - Principles of Psychology (SV 171).
 - Experimental Psychology (SV 272).
 - Three other Psychology courses.
2. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Courses

- **IA 471 Literature of Madness**
- **SV 171 Principles of Psychology**
- **SV 272 Experimental Psychology**
- **SV 375 Personality Theories**
- **SV 373 Gender Issues**
- **XX 399 Special Topics**
- **XX 499 Directed Study**

German Technical Translator's Certificate Program

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

1. A student must complete all the technical courses required by one of the Institute's degree-granting programs.

- 2. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- 3. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German, one additional course in any category.

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- 1. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- 2. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- 3. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- 4. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.



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Institute of Technology**
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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Military

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

Curriculum

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- Computational Science Major (CPLS) (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College, University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

Freshman Year	Credit
MS 101 Leadership and Personal Development.....	1
MS 102 Introduction to Tactical Leadership.....	1
MS 103 Basic Tactical Leadership	1

Sophomore Year	Credit
MS 201 Innovative Team Leadership.....	2
MS 202 Foundations of Tactical Leadership.....	2
MS 203 Foundations of Tactical Leadership II.....	2

Summer	Credit
MS 206 ROTC Basic Camp	0


ADVANCED COURSE

Junior Year	Credit
MS 301 Adaptive Team Leadership.....	4
MS 302 Leadership Under Fire	4
MS 303 Leadership Under Fire II	4

Senior Year	Credit
MS 401 Developing Adaptive Leaders.....	4
MS 402 Leadership in a Complex World.....	4
MS 403 World.....	4

Total Credits Required: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training.

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Programs of Study

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose-Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

Computational Science Major (CPLS) (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs



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Course Descriptions

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Aerospace Studies (Air Force ROTC)

LTC Schramm, MAJ Buchanan, CAPT Cordrey

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Pre: None

This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Pre: AS 101 or instructor permission

This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Pre: AS 102 or instructor permission

This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Pre: Enrollment in AS 101, AS 102, or AS 103

Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Pre: AS 103 or instructor permission

This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFOTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Pre: AS 201 or instructor permission

This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Pre: AS 202 or instructor permission

This course is a continuation of the winter quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Pre: Enrollment in AS 201, AS 202, or AS 203

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Pre: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Pre: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Pre: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Pre: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Pre: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Pre: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Pre: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Pre: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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Student Life

News

Calendars

Alumni

Athletics

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Applied Biology & Biomedical Engineering

Applied Biology and Biomedical Engineering Faculty: Ahmed, Anthony, Buckley, Coppinger, Dee, Ingram, Livesay, O'Connor, Rogge, Waite, Weiner, Xu

Applied Biology

AB 101 Essential Biology 4R-OL-4C F,W,S Pre: None

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed AB110, AB120 or AB130 cannot receive credit for taking AB101.

AB 102 Nutrition 4R-OL-4C W Pre: none

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for AB or BE majors and not as an AB elective.

AB 110 Cell Structure and Function 3R-3L-4C F,S Pre: None

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

AB 120 Comparative Anatomy & Physiology 3R-3L-4C W Pre: None

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

AB 130 Evolution and Diversity 3R-3L-4C S Pre: None

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

AB 191 Special Topics in Applied Biology XR-OL-XC Arranged Pre: Consent of instructor

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed AB course.

AB 210 Mendelian and Molecular Genetics 3R-3L-4C F Pre: AB 110 or instructor consent

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

AB 220 Prokaryotic Cell and Molecular Biology 3R-3L-4C W Pre: AB 110 or instructor consent

Discusses the essential properties of eubacteria and archaea. Bacterial nutrition, growth, genetics and structural and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

AB 230 Eukaryotic Cell and Molecular Biology 3R-3L-4C S Pre: AB 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

AB 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111, or CHEM 105 or CHEM 201, or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

AB 301, 302 Biology Colloquium 1R-0L-1C F, W Pre: Junior standing

A discussion of selected timely topics and preparation for senior research.

AB 310 Plant Structure & Function 3R-3L-4C S Pre: AB 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

AB 320 Ecology 3R-3L-4C F Pre: AB 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

AB 330 Evolutionary Biology 4R-0L-4C W Pre: AB 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

AB 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Pre: AB120, and Jr/Sr standing or consent of instructor

Designed to introduce applied biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

AB 401 Biology Colloquium 2R-0L-2C W Pre: Senior standing

Oral presentations and discussion of selected timely topics.

AB 410 Infection and Immunity 4R-0L-4C Arranged Pre: AB 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

AB 411 Genetic Engineering 4R-0L-4C Arranged Pre: AB 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

AB 421 Applied Microbiology 4R-0L-4C Arranged Pre: AB110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

AB 431 Genomics and Proteomics 4R-0L-4C S Pre: AB210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

AB 441 Virology 3R-3L-4C Pre: AB110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

AB 451 Cancer Biology 4R-0L-4C Pre: AB210, or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

AB 461 Evolutionary Medicine 4R-0L-4C Arranged Pre: AB130 and AB210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

AB 491 Special Topics in Applied Biology XR-0L-XC Arranged Pre: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed AB course.

AB 492 Directed Study in Applied Biology XR-XL-XC Arranged Pre: Consent of instructor

Covers applied biology material of mutual interest to the student and instructor which cannot be experienced in any other listed AB course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the ABBE department is required to use this course to fulfill AB elective credit requirements.

AB 499 Senior Thesis Research 0R-12L-4C F, W, S Pre: Senior standing

Laboratory research under the direction of a faculty mentor. Culminates in an oral research presentation and publication of a Senior Thesis.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4C W Pre: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE201 Biomedical Measurements 3R-3L-4C Pre: BE100, ES203

Discuss the measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors (temperature, force, pressure, velocity, etc), and basics of PIC microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I: 3R-3L-4C F Pre: AB120

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Pre: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of "cradle to cradle" design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II: 3R-3L-4C W Pre: BE310

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3C C W Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE351 and BE361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Instrumentation and Signal Processing 3R-3L-4C F Pre: Pre: BE 201 and ES 203, or consent of instructor

Topics include Circuit analysis, frequency analysis, biomedical transducers, design of biomedical devices, and introduction to imaging techniques.

BE 350 Biocontrol Systems 4R-0L-4C W Pre: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE351: Biomedical Engineering Lab 1R-3L-2C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331 and BE361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE352: Biomechanics Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE353: Biomaterials Lab 0R-3L-1C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 390 Principles of Biomedical Engineering Design 1R-3L-2C S Pre: BE 201, Coreq: EM204, or consent of instructor

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 410 Biomedical Engineering Design I 3R-3L-4C F Pre: BE390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C W Pre: BE410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C S Pre: BE420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 212, and SR/GR standing

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics- based clinical applications. Same as OE 435. Students taking BE435/OE435 may not receive credit for BE535/OE535.

BE 482 Bioengineering Statistics 4R-0L-4C Pre: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 Special Topics in Biomedical Engineering XR-0L-XC Arranged Pre: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Pre: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 Thesis Research 0R-6L-2C F, W, S Pre: Junior or senior standing

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's advisor. BE499 may not be used as a biomedical engineering area elective.

BE 510 Biomedical Signal and Image Processing, 3R-3L-4C W Pre: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Human Physiology A 3R-3L-4C F Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class.

BE 512 Human Physiology B 3R-3L-4C W Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512).

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Pre: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Pre: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage). Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535/OE 535 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 212, and SR/GR standing

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications. For graduate credit, students must do additional project work on a topic selected by the instructor. Students taking BE535/OE535 may not receive credit for BE435/OE435.

BE 539 Multiscale Biomechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models. Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This

course will serve as a Biomechanics track elective.

BE 541 Medical Imaging 4R-0L-4C Pre: JR/SR/GR standing and consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including computed tomography, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed.

BE 543 Neuroprosthetics 3R-3L-4C Pre:BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Pre: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Pre: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Pre: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Pre: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Pre: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term. F,W,S

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual

supplementation is provided.

BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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Course Descriptions

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

Professors Anklam, Artigue, Coronell, Hariri, Henthorn, McClellan, Nolte, Sauer, and Serbezov.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Pre: None

An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 0L-0C F Pre: sophomore standing in Chemical Engineering

Career choices in chemical engineering, internship, coop, chemical industry working environment. 2-5 contact hours per quarter.

CHE 201 Conservation Principles and Balances 4R-0L-4C F Pre: CHEM 113, MA 113 and PH 111

An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties - mass, energy, charge, linear momentum - as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in analysis of chemical engineering processes will be addressed including recycle, bypass and multi-stream processes. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers. The use of computer software, especially spreadsheets, will be integrated into the course.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Pre: CHE 201

Applications of the principles of conservation of mass and energy to reactive, multiphase, and transient systems. The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances.

CHE 300 Career Preparation II 0L-0C F Pre: Junior standing in Chemical Engineering

Career choices; preparation of resume; preparation for summer positions; preparation for graduate programs. 2-5 contact hours per quarter.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Pre: CHE 201

Physical properties, fluid statics, laminar and turbulent flow of real fluids, boundary layer concept, interaction between fluid flow and contacting surfaces. Use of energy balances in design of pipe networks and pumps. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Pre: CHE 202, MA211

First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F, W Pre: CHE 303, MA212

Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Pre: CHE 110, MA211, MA212 or concurrent enrollment

The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE 314 Heat Transfer 4R-0L-4C F, W, Pre: CHE 202, CHE 301, MA211, MA 212

Discussion of fundamental heat transfer processes: conduction, forced and free convection, boiling and condensation, and radiation heat transfer. Mathematical analysis and computation of heat transfer and temperature profiles in solids with simple geometry. Estimation of local and overall heat transfer coefficients. Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries.

CHE 315 Materials Science and Engineering 4R-0L-4C F,S Pre: CHEM 113

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 325 Mass Transfer 4R-0L-4C W, S Pre: CHE 202, CHE 314, CHE 304

Principles of diffusion. Study of gas-liquid operations including gas absorption and distillation in equilibrium stage tray columns as well as packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium and rates of heat and mass transfer.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Pre: CHEM 360 and CHE 304

Homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions and reactors, temperature and pressure effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in CHE 405/505 must do project work on a topic selected by the instructor.

CHE 409 Professional Practice 1R-0L-1C F

Topics on professional practice, project management, contemporary and global issues in the profession are discussed by students, staff and outside speakers.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHE 314, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Pre: CHE 325, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Pre: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Design I: Process Economics and Equipment Design 4R-0L-4C F Pre: CHEM 252, CHE 325, CHE 404 or concurrent registration

Introduction to the design process; simulation to assist in process creation & analysis; synthesis of separation trains; design of separation towers, heat exchangers, pumps, compressors, expanders and other process equipment; cost accounting & capital cost estimation, trade-offs between capital and operating costs; design of reactor-separator-recycle networks.

CHE 417 Design II: Process Synthesis and Analysis 4R-0L-4C W Pre: CHE 416, CHE 404

Annual costs, earnings & profitability; process creation, optimization of process flowsheets; molecular structure design; heat & power integration; mass integration; optimal design & scheduling of batch processes. The course includes an open-ended process improvement project.

CHE 418 Design III: Capstone Design Project 0R-6L-2C S Pre: CHE 417

Completion of an open-ended design project which will include written and oral communication of intermediate status and the final design specifications.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers.

CHE 440 Process Control 4R-0L-4C W Pre: CHE 202, MA211, MA 212

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of control elements, stability criteria, and frequency response. The course at times uses a personalized system of instruction format.

CHE 441 Polymer Engineering 4R-0L-4C F Pre: CHE 404 or concurrent registration, and CHEM 251, or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 450 Air Pollution 4R-0L-4C F or W Pre: Junior or Senior standing

An introduction to air pollution and its control with special emphasis on the engineering aspects. Discussions of meteorology, health effects, sources and types of pollution, industrial control technology. Student projects.

Cross-listed with CE561.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Pre: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 465 Energy and the Environment 4R-0L-4C W or S Pre: CHE 303 or CHEM361 or ME201 or ME301 or consent of instructor

This is a survey course in which the energy needs of the world, the ways in which those needs are currently being met, the development and current usage of renewable energy, and the impact of these on the environment, specifically the impact on climate change, are examined. Life cycle analysis is also considered.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C S Pre: Junior or Senior standing

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, HAZOP analysis. Design of equipment to prevent fires and explosions. Risk assessment, including event and fault trees.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F, W, S Pre: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

Undergraduate-Graduate Courses

CHE 502 Transport Phenomena I 4R-0L-4C Pre: CHE 325 or consent of instructor

Solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal flows inside ducts and over objects in both steady and unsteady systems. Turbulent flow theories. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux, in solids and laminar flows including boundary layers. Theoretical bases for friction factors, convective heat transfer, and convective mass transfer coefficients. Dimensional

analysis.

CHE 503 Transport Phenomena II 4R-0L-4C

Energy Transport: multidimensional systems; macroscopic balances for nonisothermal systems. Mass Transport: fundamentals of ordinary diffusion, multicomponent diffusion, pressure and thermal diffusion, coupled heat and mass transfer, boundary layer analysis, turbulent transport, mass transfer coefficients, macroscopic balances.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in EP510, ME516, ECE516, CHE505, BE516 must do project work on a topic selected by the instructor.

CHE 512 Petrochemical Processes 4R-0L-4C F or W Pre: CHE 325 or consent of instructor

Multicomponent separation of petroleum by flash vaporization and by distillation. Catalytic processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas. Group projects on refinery and petrochemical processes. Material balances and economic evaluations. Application of computer design packages and spreadsheets.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Students enrolled in EP511, ME519, ECE519, CHE519, BE516 must do project work on a topic selected by the instructor.

CHE 521 Advanced Chemical Engineering Computation 4R-0L-4C

The application of advanced mathematics to chemical engineering problems. The topics include: the formulation of the partial differential equations of kinetics and heat, mass and momentum transfer problems; series solution techniques; transform solution techniques; vector formulation; numerical methods for systems of differential equations; optimization, including linear programming, combinatorial optimization, and stochastic optimization techniques.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: optimization, nonlinear control, adaptive control, multivariable systems, process dynamics, digital systems, system design.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: AB110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: AB110, CHE 325 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Programs of Study

Course Descriptions

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Advanced Placement

Graduate Studies

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Chemistry

Professors Allison, Brandt, R. DeVasher, Erwin, Morris, Mottel, Mueller, Shearer, Tilstra, and Weatherman

CHEM 105 Engineering Chemistry I 3R-3L-4C F,W,S

Topics include stoichiometry, nomenclature, reactions in aqueous solution including balancing oxidation-reduction reactions, atomic structure and periodic properties. Chemical bonding including Lewis dot structures, molecular geometry, and molecular orbital theory are considered in relation to the properties of solids, liquids, solutions and gases. Chemical kinetics along with the Arrhenius equation and nuclear reactions is covered. Not available for students who have credit for CHEM113. (Formerly CHEM 201)

CHEM 107 Engineering Chemistry II 3R-3L-4C W,S Pre: CHEM 105 or CHEM 201

Heterogeneous and homogeneous equilibria for gas-phase, solution phase, and acid/base reactions are covered. Electrochemistry, thermochemistry, and thermodynamics are also covered. Not available for students who have credit for CHEM 113. (Formerly CHEM 202)

CHEM 111 General Chemistry I 3R-4L-4C F Pre: None

The chemistry of matter. A laboratory-driven course which covers states of matter, equilibrium, solutions, and ionic equilibria. Assumes a working knowledge of algebra.

CHEM 112 General Chemistry Honors 4R-3L-5C F Pre: Advanced placement

An accelerated course covering topics in CHEM 111 and CHEM 113. An additional 3 credits will be awarded students with a grade of B or better. Enrollment is limited to those students who complete the chemistry Advanced Placement Examination with a score of 4 or who qualify on the basis of a chemistry placement examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-4C W Pre: CHEM 111

The chemistry of energy. A laboratory and reading-driven course which covers simple thermodynamic considerations, electrochemistry, chemical kinetics, and nuclear chemistry.

CHEM 115 General Chemistry III 3R-3L-4C W, S Pre: CHEM 113 or CHEM 112, or CHEM 107 or CHEM 202

A treatment of atomic structure and theories as they apply to the periodic properties of the elements. Chemical bonding and molecular geometry are also studied. The laboratory provides descriptive chemistry and logic in designing separation schemes for qualitative analysis.

CHEM 200 Career Preparation 1R-0L-1C W,S

This course is for chemistry and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with MA200. PH 200 and SV200.

CHEM 225 Analytical Chemistry 3R-4L-4C F, S Pre: CHEM 115, or CHEM 107 or CHEM 202

This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 251 Organic Chemistry I 3R-4L-4C F Pre: CHEM 115, or CHEM 107 or CHEM 202

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

An introduction to the classification of organic compounds, their structural features, including stereochemistry, and the methods used to determine structure, including IR and NMR spectroscopy; concepts related to reaction mechanisms and synthetic methods are introduced.

CHEM 252 Organic Chemistry II 3R-4L-4C W Pre: CHEM 251

Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis.

CHEM 253 Organic Chemistry III 3R-4L-4C S Pre: CHEM 252

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111 or CHEM 105 or CHEM 201 or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with AB264.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Pre: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Pre: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research under the direction of a member of the faculty selected by mutual agreement. Freshman and/or sophomore students may earn up to 2 credits and are required to submit a written report to the chemistry faculty.

CHEM 291 Introduction to Chemical Research 3R-3L-4C W Pre: CHEM 115 or CHEM 107

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members.

CHEM 304 Glassblowing 1R-3L-1C S Pre: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4C F Pre: CHEM 225

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Pre: CHEM 225

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Pre: CHEM 252 or CHEM 230

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Pre: CHEM 330 and AB 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C W, S Pre: CHE 303, CHE 304, and CHEM115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Pre: CHEM 115, MA 212 and MA 381

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the

applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Pre: CHEM 115, or CHEM 105 or CHEM 201, MA 212, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 371 Environmental Analytical Chemistry (3R-4L-4C) F Pre: CHEM251 (or concurrent enrollment), and CHEM 225 and CHEM 264

This course is a laboratory-driven course where processes involved in performing environmental analytical chemistry are addressed. The focus of this course is on the chemical principles, analytical theory, instrumentation, and methods employed to quantitatively and qualitatively analyze pollutants in soil, water, biological tissues, and the atmosphere. Several techniques will be included in the course: sampling (obtaining a representative sample of complex system); sample preparation (extraction, clean-up, pre-concentration, derivitization, digestion, etc.); data acquisition (The laboratory will include use of EPA/ASTM methods/protocols, method development, etc.); and data handling and analysis (statistics, signals, noise, etc.).

CHEM 401 Chemical Communication I 1R-0L-1C F

Students will engage in both oral and written communication that will culminate in a professional seminar and formal research report at the completion of this course sequence. Students will compose the literature survey and experimental sections of their formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 402 Chemical Communication II 1R-0L-1C W Pre: CHEM 401

Students will engage in both oral and written communication that will culminate in a professional seminar and formal research report at the completion of this course sequence. Students will construct the data, results, and analysis sections of their formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will develop an outline for their professional seminar. Students will also be required to attend the chemistry department's seminar series.

CHEM 403 Chemical Communication III 1R-0L-1C S Pre: CHEM 402

Students will engage in both oral and written communication that will culminate in the delivery of a professional seminar and a written formal research report, consistent with the guidelines presented in The ACS Style Manual.

CHEM 430 Advanced Biochemistry 4R-0L-4C S Pre: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 431 Biochemical Instrumentation 3R-4L-4C Pre: AB 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 433 Biochemistry Laboratory 0R-4L-1C S Coreq: CHEM 430

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Pre: CHEM 252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Pre: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 445 Organometallic Chemistry 4R-0L-4C S Pre: CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 451 Organic Structure Determination 2R-8L-4C S Pre: CHEM 253 or permission of instructor
Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 452 Synthetic Organic Chemistry 4R-0L-4C F or W Pre: CHEM 253
A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 454 Theoretical Organic Chemistry 4R-0L-4C W Pre: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor
Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 455 Natural Products 4R-0L-4C Pre: CHEM 253 or permission of instructor
A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 457 Synthetic Polymer Chemistry 4R-0L-4C Pre: CHEM 252
Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 461 Advanced Physical Chemistry 4R-0L-4C Pre: CHEM 363
Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 462 Physical Polymer Chemistry 4R-0L-4C Pre: CHEM 361 or CHE 303
Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Pre: CHEM 251 or CE 564 or consent of instructor
This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: permission of instructor
Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F, W, S Pre: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.
Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: Permission of instructor
Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Pre: CHEM291
Research under the direction of a member of the faculty selected by mutual agreement. Students may earn a maximum of 18 credits between CHEM 290 and CHEM 490. Students may register for 1 to 3 credits per quarter.

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Course Descriptions

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Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Civil Engineering

CE 321 Structural Mechanics I 4R-0L-4C F Pre: EM 203

Sophomore Engineering

Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Pre: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Pre: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE 400 Career Preparation Seminar 1R-0L-0C S Pre: CE 489

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 410 Senior Project 0R-8L-4C On Demand Pre: Senior class standing

Gives the student the opportunity to work on a civil engineering design or research project of the student's own choice, but which has met the approval of the staff prior to the start of the quarter. Requires presentation of oral and written reports. Not a regular elective offering.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills.

CE 421 Structural Mechanics II 4R-0L-4C W Pre: CE 321

Matrix methods of structural analysis for two- and three- dimensional indeterminate structures. Force method, stiffness method, introduction to finite element analysis for civil engineers.

CE 424 Composite Material Mechanics 4R-0L-4C On Demand Pre: CE 321

Introduces various laminated composite materials such as reinforced plastics, laminated glass, plywood, laminated timber, and fiber-structural sandwich. Emphasis is on beam theory and plane stress analysis for such materials.

CE 430 Structural Design in Timber I 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of modern structures constructed of timber. Considers fasteners and their significance in design. Develops design criteria and their application to plane and three dimensional structures.

CE 431 Structural Design in Steel I 3R-0L-3C S Pre: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Pre: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 433 Structural Design in Steel II 4R-0L-4C On Demand Pre: CE 431

Covers the analysis and design of the various elements of a steel structure within the framework of the total structure. Includes composite design, plate girders, and multi-story building frames.

CE 434 Structural Design in Concrete II 3R-3L-4C Pre: CE 432

Advanced topics in reinforced concrete analysis and design such as strut-and-tie modeling, and strengthening with fiber reinforced polymers.

CE 435 Bridge Engineering 4R-0L-4C On Demand Pre: CE 321

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Includes methods and procedures for the analysis and design of bridge structures. Considers standards and procedures for inspections and ratings of bridges and methods to increase the load capacity of existing bridges. Includes field inspections.

CE 436 Foundation Engineering 4R-0L-4C S Pre: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Pre: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C F Pre: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 444 Pavement Design and Highway Construction 4R-0L-4C On Demand Pre: CE 320

Introduction to analysis and design of rigid and flexible pavement systems; subgrade, subbase, base and surfaces; specifications, material testing and construction methods for soil stabilization, flexible and rigid pavements; pavement evaluation, maintenance and reconstruction.

CE 445 Construction Methods and Equipment 4R-0L-4C F Pre: CE 201 and CE 336, Co: CE 442

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Pre: CE 431 & CE 432

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will also look at environmentally safe and renewable building materials, energy efficient construction techniques, indoor air quality and moisture problems, etc. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Pre: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Co: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 471 Water Resources Engineering 4R-0L-4C W Pre: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Transportation Planning 4R-0L-4C On Demand Pre: Junior class standing

Analyzes the transportation planning process. Stresses goals and approaches to solutions as related to the urban transportation problem. Includes a class project.

CE 481 Transportation Engineering 4R-0L-4C W Pre: Senior class standing

Study of transportation functions and transportation systems including land, air and marine modes; transportation system elements including travel way, vehicle, controls and terminals; emphasis on highway geometric design.

CE 482 Urban Planning 4R-0L-4C On Demand Pre: Junior class standing

Applies general principles of systems analysis and control to urban and regional planning. Covers human settlements, location theory, simulation, plan formulation, selection and implementation. Includes a class project.

CE 489 Civil Engineering Design & Synthesis 5R-9L-8C F,W,S (1 R-3L-2C, fall; 3R-3L- 4C, winter; and 1R-3L-2C spring) Pre: RH 330, CE 460 Co-Req: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be undertaken by small teams of students to implement principles used in planning, design, and synthesis. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. The course is offered through the fall, winter, and spring at a rate of two credits per term for the fall and spring and four credits for the winter. No credit will be granted for the fall and/or winter terms alone. Eight credits will be granted after completion of the entire course in the spring term.

CE 490 Directed Studies F,W,S 1-4 C Arranged. Pre: Approval of department head, adviser, and course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

Undergraduate-Graduate Courses

CE 520 Plates and Shells 4R-0L-4C On Demand Pre: CE 421 and MA 212

Development of classical plate equation and boundary conditions; solution of problems in rectangular and polar coordinates. Development of membrane and bending theories for shells of revolutions; solution to domes and storage tanks.

CE 522 Advanced Finite Element Analysis 4R-0L-4C On Demand Pre: CE 421

Development of finite element methods for solving plane strain, plane stress and field problems. Utilizes readily available finite element computer programs. Requires additional development of user computer programs.

CE 523 Structural Dynamics 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of structures subjected to dynamic loads. Covers elastic and inelastic responses with applications to earthquake design, blast-resistant structures and bridge vibration.

CE 525 Buckling Strength of Structures 4R-0L-4C On Demand Pre: CE 321

Discusses the buckling phenomenon of prismatic bars subjected to combined axial and transverse loads. Considers elastic and inelastic instability. Includes buckling of beams, columns, curved bars, rings, plates, trusses and rigid frames.

CE 530 Structural Design in Timber II 4R-0L-4C On Demand Pre: CE 430

Presents the analysis and design of structures constructed of timber. Tapered beams, curved beams, box beams, stressed-skin panels, tapered columns, built-up columns, laminated arches, plate connected trusses, pole structures, diaphragms, shearwalls.

CE 531 Structural Design in Masonry 4R-0L-4C S Pre: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 533 Behavior of Metal Structures 4R-0L-4C On Demand Pre: CE 433

Discusses the behavior of metal connectors, members and structures. Studies the significance of this behavior in terms of design and the development of specifications. This course is closed to students who have successfully completed CE 433 Structural Design in Steel II.

CE 534 Behavior of Concrete Structures 4R-0L-4C On Demand Pre: CE 432

Studies the behavior of beams, slabs, and columns of reinforced concrete, prestressed concrete and composite construction from the standpoint of design and the development of specifications.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C On Demand Pre: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Pre: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 561 Air Pollution 4R-0L-4C W Pre: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Treatability Studies 2R-6L-4C On Demand Pre: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 563 Unit Operations in Environmental Engineering 4R-0L-4C F Pre: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Pre: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The

carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Pre: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Pre: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Pre: CE 471

Environmental planning and management strategies are examined using computer simulation models. Students will be introduced to some of the most widely used models in the fields of hydrology, hydraulics, and stormwater quality (nonpoint source pollution).

CE 568 Applied Contaminant Transport Modeling 4R-0L-4C On Demand Pre: CE 460 or consent of instructor

Environmental planning and management strategies are examined using computer simulation models. Emphasis is on pollutant transport in various media and emerging pollution issues. Students are introduced to some of the most widely used models in the field of environmental engineering. Students also develop at least one pollutant transport model using common software such as EXCEL, MATHCAD.

CE 569 Environmental Systems Optimization 4R-0L-4C Pre: Senior or Graduate class standing

Application of the principles of operations research to constrained optimization of environmental systems. Typical topics include strategies for non-linear searches, linear programming, dynamic programming, etc.

CE 570 Fluid Mechanics in Water Resources Engineering 4R-0L-4C On Demand Pre: CE 371

Presents steady and unsteady flow problems in open channels and pipes, problems dealing with laminar and turbulent boundary layers, and problems including diffusion and dispersion. There will be occasional laboratory work to demonstrate physical modeling in water resources engineering.

CE 573 Groundwater Analysis 4R-0L-4C Pre: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Pre: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Pre: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Computer Science & Software Engineering

Professors Anderson, Bohner, Boutell, Chenoweth, Clifton, Defoe, Laxer, Mellor, Mohan, Mutchler, Shillingford, and Wollowski

CSSE 120 Introduction to Software Development 3R-3L-4C F, W, S

An introduction to procedural and object-oriented programming with an emphasis on problem solving. Students will solve problems by developing software in both an interpreted language (Python) and a compiled language (C). Problems may include visualizing scientific or commercial data, interfacing with external hardware such as robots, or solving numeric problems from a variety of engineering disciplines. Procedural programming concepts covered include data types, variables, control structures, arrays, and data I/O. Object-oriented programming concepts covered include object creation and use, object interaction, and the design of simple classes. Software engineering concepts covered include testing, incremental development, understanding requirements, and teamwork.

CSSE 132 Introduction to Computer Systems 3R-3L-4C S Pre: CSSE 120

Provides students with an understanding of system level issues and their impact on the design and use of computer systems. Examination of both hardware and software layers. Basic computation structures and digital logic. Representation of instructions, integers, floating point numbers and other data types. System requirements, such as resource management, security, communication and synchronization, and their hardware and/or software implementation. Exploration of multiprocessor and distributed systems. Course topics will be explored using a variety of hands-on assignments and projects.

CSSE 220 Object-Oriented Software Development 3R-3L-4C F,W,S Prerequisite: CSSE 120

Object-oriented programming concepts, including the use of inheritance, interfaces, polymorphism, abstract data types, and encapsulation to enable software reuse and assist in software maintenance. Recursion, GUIs and event handling. Use of common object-based data structures, including stacks, queues, lists, trees, sets, maps, and hash tables. Space/time efficiency analysis. Testing. Introduction to UML.

CSSE 221 Fundamentals of Software Development Honors 3R-3L-4C F Prerequisite: A score of 4 or 5 on the APCS A exam or permission of instructor

This course is intended for students who have sufficient programming experience to warrant placement in an accelerated course covering the topics from CSSE 120 and CSSE 220. This course will satisfy the prerequisite requirements for courses that have CSSE 220 as a prerequisite.

CSSE 230 Data Structures and Algorithm Analysis 3R-3L-4C W,S Prerequisites: CSSE 220 or CSSE 221 with a grade of C or better, and MA 112

This course reinforces and extends students' understanding of current practices of producing object-oriented software. Students extend their use of a disciplined design process to include formal analysis of space/time efficiency and formal proofs of correctness. Students gain a deeper understanding of concepts from CSSE 220, including implementations of abstract data types by linear and non-linear data structures. This course introduces the use of randomized algorithms. Students design and implement software individually, in small groups, and in a challenging multi-week team project.

CSSE 232 Computer Architecture I 3R-3L-4C F, W Prerequisites: CSSE 120 and ECE 130

Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic,

Aerospace Studies (Air Force ROTC)

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Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control.

Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prerequisite: CSSE 220 or CSSE 221

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE290 Special Topics in Computer Science 1 - 4C Arr. Prerequisite: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prerequisite: CSSE230 and MA275

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arr Prerequisites: CSSE 220 or CSSE 221, and MA 212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W, S Prerequisites: CSSE 220 or CSSE 221, and CSSE 232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prerequisite: MA 275 and CSSE 230 (or concurrent enrollment in CSSE 230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary APIs for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C F Prerequisites: CSSE 220 or CSSE 221, and MA 212

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 371 Software Requirements and Specification 4R-0L-4C F Prerequisite: CSSE 230, RH 330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requisite: CSSE 371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict management. Professional issues including career planning, lifelong learning, software engineering ethics, and

the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prerequisite: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Architecture and Design 4R-0L-4C W Prerequisite: CSSE 371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 4R-0L-4C S Prerequisite: CSSE 374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prerequisite: CSSE 230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 377 Software Architecture and Design II 4R-0L-4C F Pre: CSSE 374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 402 Theory and Practice of Garbage Collection 4R-0L-4C S (even years) Prerequisite: CSSE 332

Garbage collection (GC) is a method of automatically reclaiming dynamically allocated storage that an application no longer needs. In this course, students will explore the classical problems of garbage collection such as detecting unused objects and reclaiming the space allocated to them. Students will survey the GC literature to become familiar with the current state of the art and future research directions. Students will explore techniques used to implement state-of-the-art garbage collection algorithms and will design and implement garbage collectors for a memory-managed language (e.g., Java, C#, php, or Python).

CSSE 403 Programming Language Paradigms 4R-0L-4C F (even years) Prerequisite: CSSE 304

A survey of some current and emerging programming languages, focusing on unique language paradigms, ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prerequisites: CSSE 232, CSSE 304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C F Prerequisite: CSSE 230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C S Prerequisite: CSSE 220 or CSSE 221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 433 Advanced Database Systems 4R-0L-4C S Prerequisite: CSSE 333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions,

transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prerequisites: CSSE 332 and MA 275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 451 Advanced Computer Graphics 4R-0L-4C W (even years) Prerequisite: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence 4R-0L-4C Arr Prerequisite: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C S (odd years) Prerequisites: CSSE 220 or CSSE 221, and MA 212 (MA 371 or MA 373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prerequisites: Junior standing, MA212 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C F Prerequisites: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C W Prerequisites: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 479 Cryptography 4R-0L-4C S Prerequisites: CSSE 220 or CSSE 221, and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 481 Web-Based Information Systems 4R-0L-4C F (odd years) Prerequisite: CSSE 230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE487 Senior Research Project I 4C Arr Prerequisite: RH330 and senior standing

CSSE488 Senior Research Project II 4C Arr Prerequisite: CSSE487

CSSE489 Senior Research Project III 4C Arr Prerequisite: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arr Prerequisite: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arr Prerequisite: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arr Prerequisite: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arr Prerequisite: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arr Prerequisite: RH 330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arr Prerequisite: CSSE 494

CSSE 496 Senior Thesis III 4C Arr Prerequisite: CSSE 495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Project I 4C F Prerequisite: CSSE 371

CSSE 498 Senior Project II 4C W Prerequisite: CSSE 374 and CSSE 497

CSSE 499 Senior Project III 4C S Prerequisite: CSSE 498

Group software engineering project requiring completion of a software system for an approved client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure.



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Minors

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Electrical & Computer Engineering

Professors C. Berry, Black, Doering, Eccles, Grigg, Herniter, Hoover, Hudson, Moore, Mu, Padgett, Radu, Rostamkolai, Simoni, Song, Throne, P. Walter, Wheeler, and Yoder.

ECE 130 Introduction to Logic Design 4R-0L-4C F,W,S Pre: None
Combinational logic analysis and design, Boolean algebra, gate-level optimization, switch-level circuits, propagation delay, and standard combinational components. Sequential circuit analysis and design, flip-flops, timing diagrams, registers, counters, and finite state machine controllers. Design projects using circuit simulator and implementation in hardware.

ECE 160 Engineering Practice 0R-4L-2C F, W Pre: none
The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

ECE 200 Circuits & Systems 3R-3L-4C F,W,S Pre: ES 203 with a grade of C or better, MA 221
Mutual inductance. First- and second-order circuits. Laplace transform. Applications in the s-domain. Bode diagrams. Passive and active filters. Two-port networks. Integral laboratory includes circuit design problems.

ECE 203 DC Circuits 3R-3L-4C F, W, S Pre: MA111 and PH112
Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

ECE 204 AC Circuits 3R-3L-4C F, W, S Pre: ECE203 with a grade of C or better and PH113
Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Dynamical Systems 3R-3L-4C F, W, S Pre: ECE204 and MA211
Review of matrix and differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical, mechanical, and thermal systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C F,W,S Pre: MA 211
A course designed for engineers (other than electrical or computer) covering analysis of passive DC circuits, introduction to op-amps, steady-state sinusoidal circuit analysis and power in AC systems. EE or CPE majors may not take this course as a free elective.

ECE 207 Electrical Engineering 3R-3L-4C F,W Pre: ES 203
A course designed for engineers (other than electrical or computer) covering AC power, three-phase systems, magnetic circuits, transformers, machines, strain gauges, RTDs and thermocouples, noise and shielding, and feedback systems. Integral laboratory. EE or CPE majors may not take this course as a free elective.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

ECE 230 Microcontrollers and Computer Architecture 3R-3L-4C F, W, S Pre: ECE130, CSSE120

Microcontroller architecture, instruction sets, assembly language programming, interrupts, and device interfacing. Integral laboratory and design project.

ECE 250 Electronic Device Modeling 3R-3L-4C F,W,S Pre: ECE 204, MA 211

Modeling, analysis, and simulation of electronic circuits that contain two-terminal and three-terminal semiconductor devices. Large-signal, biasing, and small-signal analysis models. Introduction to wave shaping circuits, switching circuits, and amplifiers. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Pre: ECE 205, MA 211, MA 212

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,W,S Pre: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Discussion of a current ethical issue. Integral laboratory.

ECE 320 Linear Control Systems 3R-3L-4C F,W,S Pre: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C F,S Pre: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C F,S Pre: CSSE 232

Pipelining, memory hierarchy, busses, instruction level parallelism, cost-performance tradeoffs, and review of new topics in areas of computer architecture or parallel processing. Team research project. Complements CS 332.

ECE 333 Digital Systems 3R-3L-4C F,W,S Pre: ECE 130, ECE 250

Capabilities and limitations of digital CMOS logic devices. Design and evaluation of combinational and sequential logic circuits using Programmable Logic Devices. System integration with multiple components (FPGA, GAL, discrete components). CAD tools for design entry, timing simulation, and mapping to target devices. Troubleshooting using laboratory instrumentation. Laboratory notebooks. Informal reports. Integral laboratory.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Pre: ECE 204, MA 211, MA 212

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Pre: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,W Pre: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 351 Analog Electronics 3R-3L-4C F,W,S Pre: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal

properties of op-amps. Integral laboratory.

ECE 361 Engineering Practice 1R-3L-2C F,W Pre: ECE 200

Creativity, project design specifications, team roles, effective conduct of team meetings, written and oral communication skills, ethics and professionalism, completion of team project(s).

ECE 362 Principles of Design 3R-0L-3C W, S

Pre for EE: ECE160, ECE250, ECE300, ECE340

Pre for CPE: ECE160, ECE250, ECE300

Pre for CS and SE majors: CSSE 374

Pre for ME majors: EM 103, ES 205, and ECE 207

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3½R-1½L-4C F, W Pre: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, wind, and fuel cell technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C F, W Pre: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C F,W,S Pre: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Pre: Consent of instructor

Special design or research projects.

ECE 410 Communication Networks 4R-0L-4C Pre: Senior standing or consent of instructor

Layered architectures. Circuit and packet switching. ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Reliable message transport, internetworking.

ECE 412 Software Defined Radio 4R-0L-4C S Pre: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front-end, and clock-jitter of the A/D. As a course project students will design and simulate a complete software-defined radio.

ECE 414 Wireless Systems 4R-0L-4C Pre: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Pre: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

ECE 418 Fiber Optic Systems 4R-0L-4C W Pre: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing systems, and optical signal processors. Topics include component overview, basic system design, and expected degradations along with mitigation techniques. An oral presentation of a research project is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for

layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ECE 420 Nonlinear Control Systems 3R-3L-4C Pre: ECE 320 or ME 406

Modeling nonlinear systems. Use of modeling software to design nonlinear control systems. Intuitive control strategies. Fuzzy control, computer and hardware implementation of fuzzy controllers, adaptive fuzzy control. Integral laboratory.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Pre: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 451 Nonlinear Electronics 3R-3L-4C Pre: ECE 351

Analysis and design of Class C and D amplifiers, high-power switching amplifiers, negative-resistance oscillators, low-noise transistor and operational amplifier circuits, and parametric amplifiers. Emphasis on nonlinear and time-varying circuit analysis and design techniques. Integral laboratory.

ECE 452 Power Electronics 3R-3L-4C Pre: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Pre: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, S Pre: ECE 362

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C F, W, S

Pre for EE: ECE310, ECE320 ECE333, ECE341, ECE351, ECE370 or ECE371,ECE380, ECE460

Pre for CPE: CSSE332, ECE331, ECE332, ECE333, ECE342, ECE351, ECE380, ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W, S Pre: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers.

ECE 470 Power Systems I 3R-3L-4C Pre: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C Pre: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C Pre: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C Pre: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow

control. Principles of state estimation. Integral laboratory.

ECE 480/PH 437 Introduction to Image Processing 3R-3L-4C Pre: MA 212 and Junior standing

Basic techniques of image processing. Discrete and continuous two-dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory. Same as PH 437.

ECE 481 Electronic Music Synthesis 4R-0L-4C Pre: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Pre: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Pre: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Engineering Projects and Design 2R-6L-4C Pre: Senior standing

Aspects of design and design presentations. Development of preliminary design and proposal for hardware project. Formal proposal and component selection. Construction, testing, and performance demonstration of previously designed project. Formal final report and oral presentation.

Undergraduate-Graduate Courses

ECE 510 Error Correcting Codes 4R-0L-4C Pre: Graduate standing, or ECE310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C Pre: Graduate standing, or ECE 310 and MA 381 with grades of B or better, or consent of instructor

Design of digital communication systems. Topics to be chosen from: Channel characterization, data compression and source coding, baseband data transmission, noise modeling, probability of error, optimal receiver structures, modulation methods, synchronization.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Students enrolled in EP510, ME516, ECE516, CHE505, BE516 must do project work on a topic selected by the instructor.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Students enrolled in EP511, ME519, ECE519, CHE519, BE516 must do project work on a topic selected by the instructor.

ECE 520 Discrete-Time Control Systems 3R-3L-4C W Pre: Graduate standing, or ECE 320 or ME 406 with grade of B or better, or consent of instructor

Digital control. Z-transform, sampling systems, sampled data control systems. Digital compensator (filter) design. Compensator sign pre- and post-conditioning. Discrete state-variable model. Integral laboratory.

ECE 521 Modern Control Systems 3R-3L-4C Pre: Graduate standing, or ECE 320 or ME 406 with a grade of B or better, or consent of instructor

State variable modeling of physical systems. Lagrangian formulations, applications of linear algebra, controllability, observability, state feedback design, design of observers. Laboratory projects emphasize control system design using state variable methods. Integral laboratory.

ECE530 Advanced Microcomputers 3R-3L-4C Pre: Graduate Standing, or ECE430 with a grade of B or better, or ECE331 with a grade of B or better, or consent of instructor.

Design of a microcomputer using a big honkin' microprocessor. Architecture and assembly programming. Integral laboratory.

ECE531 Microprogrammable Microcomputers 3R-3L-4C Pre: Graduate standing, or ECE430 with a grade of B or better, or consent of instructor

Architecture and application of microprogrammed CPU's. Microprogrammed control, hardwired control. Students will be required to develop their own microprogrammed CPU. Integral laboratory.

ECE532 Advanced Computer Architecture 4R-0L-4C Pre: Graduate standing, or ECE332 with a grade of B or better, or both ECE530 and ECE531, or consent of instructor

Selected topics in computer architecture depending on interests of class and instructor. Projects investigating current issues in computer architecture.

ECE533 Programmable Logic System Design 3R-3L-4C Pre: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Digital system-on-chip design techniques, including an advanced hardware description language, test-benches and verification, area and timing optimization, embedded microprocessors, and design for testing. Integral laboratory using contemporary CAD tools and FPGA devices.

ECE534 High-Speed Digital Design 4R-0L-4C W Pre: Graduate Standing, or ECE340 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal integrity issues in high-speed digital systems at printed-circuit board (PCB) and chassis levels. Frequency spectrum of digital signals. Frequency behaviors of passive components. Behavior models of drivers and receivers. Transient behaviors of transmission lines. Time-domain reflectometry. Signal reflection and ringing on printed-circuit board. Impedance discontinuity and matching. Load termination techniques. Capacitive and inductive crosstalk. Ground noise. Power plane noise and resonance. High-speed PCB design guidelines. PCB simulation tools.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C Pre: CSSE 232 with grade of B or better, or ECE333 with either a grade of B or better, or consent of instructor, or graduate standing

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Wave-guide structures, scattering parameters, passive components, active components, computer-aided design of amplifiers, oscillators and mixers, microwave/millimeter-wave systems, microwave and millimeter-wave integrated circuits.

ECE542 Advanced Electromagnetics 4R-0L-4C Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, power and energy, material properties, waves, reflections, radiation, EM field theorems, boundary value problems, skin effect.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE550 Linear Active Networks 3R-3L-4C Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Indefinite admittance matrix and expansion of the two-port methods of linear network analysis and design. Brune's tests. Llewellyn's stability criteria for two-port networks. Optimum terminations and mismatch design. Neutralization and unilateralization of amplifiers. Oscillators. Computer-aided design and analysis are emphasized. Integral laboratory.

ECE551 Digital Integrated Circuit Design 3R-3L-4C Pre: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C Pre: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Instrumentation amplifiers. A/D and D/A converters. Shock protection. Generation, recording and analysis of biological potentials (ECG, EMG, EEG). Ultrasound techniques and instrumentation. X-ray CAT techniques. Project involving the design of a significant instrument will run throughout the course. No laboratory, but emphasis on computer simulation of the circuits studied.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C W Pre: Graduate standing, or ECE351 with a grade of B or better or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE580 Digital Signal Processing 4R-0L-4C W Pre: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Pre: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE 582/PH 537 Advanced Image Processing 3R-3L-4C Pre: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as PH 537.

ECE 583 Pattern Recognition 3R-3L-4C S Pre: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 597 Special Topics in Electrical Engineering 4C Pre: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C arranged

Thesis topic selected in consultation with adviser. Graduate students only.





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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Management

Professors Downing, Kline, Schumacher and Stamper

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4C

Pre: Junior, Senior, or consent of instructor

Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC

Pre: **MG 461 or consent of instructor**

Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC

Pre: **MG 462 or consent of instructor**

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C, Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT520 Accounting for Technical Managers 4R-0L-4C - Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C, Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Leadership, Change and Organizational Culture 4R-0L-4C - Management

Review of fundamental activities (planning, organizing, leading, controlling) related to the management of organizations. The concepts and techniques for maximizing the effectiveness of human resources in the achievement of organizational and project goals are emphasized. Topics include communication, team process, motivation, selection, development, and appraisal. Special focus is given to the management of human resources in a technical environment.

EMGT523 Marketing in New Product Development 4R-0L-4C, - Management

A study and overview of the components of marketing principles and how those mesh with management in a technical environment. Topics will include activities associated with product, price, promotion, and distribution and how these impact the technical manager from idea generation through delivery to and service for the customer.

EMGT524 Production/Operations Management 4R-0L-4C, Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT 525 Human Resources Management 4R-0L-4C Management Elective

Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Technology Management and Forecasting 4R-0L-4C, Technical or Management

Elements of managing the growth and operation of the technological systems. Technology forecasting tools including expert methods, quantitative trend analysis, simulation, and gaming. Consideration of secondary forecasts, especially those of social and economic nature. Techniques for enhancing creativity, managing multi-disciplinary projects and impact assessment techniques are considered. Computer-based forecasting tools are applied.

EMGT527 Project Management 4R-0L-4C - Technical or Management

Addresses the major issues and techniques of project management, including team building, project evaluation and selection, scheduling techniques, quality management, development of negotiation and conflict management skills. Also examines project management success factors. Uses a large scenario planning exercise and several case studies to illustrate course content. Can be used as part of the technical or management core.

EMGT531 Economics for Technical Managers 4R-0L-4C - Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C - Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C - Management

The core of this course is the presentation of the Constructivist theory of communication and its application. Students are exposed to ethnographic interview methods and the concept of culture shock using the BAFA role-play simulation. Discussion of organizational culture includes a review of publications on this topic, the impact of culture on organizations, as well as strategies for change. May be used as a management core class.

EMGT534 Management Science 4R-0L-4C F (even years) Pre: Senior or graduate standing Technical or Management

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-0L-4C, Management

Reviews the strategy literature and the issues surrounding strategy implementation in the context of organizational change. Includes a team project that explores the strategic implications of globalization for specific industries during the next 10 years and the construction of scenarios as a tool for understanding and communication. Individual students will develop and evaluate strategy for a specific organization within the scenarios developed in the team project.

EMGT540 Fundamentals of Engineering Management 4R-0L-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT 551 Intellectual Property for Engineers and Scientists 4R-0L-4C Technical or Management Elective

Examines the influence intellectual property law has on the professional practice of engineers, scientists and engineering managers. Topics to be considered include: extracting value from intellectual property; patentable subject matter; novelty and loss of right; non-obviousness requirement; utility requirement; patent prosecution; patent litigation; designing around valid US patents; international patent rights; copyrights; trade secrets; and trademarks.

EMGT 552 Business Law for Technical Managers 4R-0L-4C Management Elective

Introduces the legal issues that will likely arise during a lifetime of employment at the management level. Topics to be considered include: business ethics; dispute resolution; intentional torts; negligence and strict liability; criminal law and procedure; contracts, sales, warranties, and products liability; negotiable instruments; bankruptcy; employment law; labor law; business organizations; consumer law; and real property law.

EMGT 561 Failures of Engineered Systems 4R-0L-4C Technical or Management Elective

Reviews past failures of engineered systems in order to improve an engineering manager's ability to anticipate, prevent, and respond to failures. The technical, human factor, and organizational root causes of the failures of engineered systems are examined. Case studies are used to illustrate the techniques that have been developed to analyze, investigate and prevent failures. Additionally, regulatory and legal responses to failures are also explored.

EMGT 585 Statistics for Technical Managers 4R-0L-4C Technical Elective

Examines basic statistics and probability while focusing on concepts most relevant to becoming an effective Engineering Manager. Students will learn to collect and analyze data to make statistically sound managerial decisions. Discussions related to descriptive statistics, hypothesis testing, confidence intervals, power calculations, correlation, linear/multiple regression, and analysis of variance (ANOVA). Students will complete a graduate-level project utilizing course concepts.

EMGT586 Supply Chain Management 4R-0L-4C, Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization.

EMGT587 Systems Engineering 4R-0L-4C, Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-0L-4C - Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-0L-4C - Technical

Provides a comprehensive introduction to manufacturing systems covering the behavior laws at work in batch production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in laws for manufacturing that help managers understand basic factory physics.

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Pre: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Mechanics

All courses in the engineering mechanics area are the responsibility of the Civil and Mechanical Engineering Departments.

CLSK 100 College and Life Skills 1R-0L-1C F Pre: None

This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

EM 101 Statics 2R-0L-2C W Pre: None

Covers static force analysis. Introduces scalars and vectors with applications to the study of forces, moments, and couples. Stresses free body diagrams with engineering examples.

EM 103 Introduction to Design 1R-2L-2C S Pre: None

Introduces the engineering design process including problem definition, analysis, alternate solutions, specifications of final solution, and techniques of oral and written communications. Stresses the importance of teamwork through group design efforts.

EM 104 Graphical Communications 1R-2L-2C F Pre: None

Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication.

EM 120 Engineering Statics 4R-0L-4C F,S Pre: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, shear and bending moment diagrams, friction, and area moments of inertia. Emphasizes free-body diagrams.

EM 121 Statics and Mechanics of Materials I 4R-0L-4C F,S Pre: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, and strength and elastic deflection of engineering materials due to loads applied axially. Emphasizes free-body diagrams.

EM 202 Dynamics 4R-0L-4C F Pre: MA 112 and EM 120 or PH 111

Kinematics and kinetics of particles in space and rigid bodies in plane motion. Applications of the principles of Newton’s laws, work-energy, impulse-momentum, and conservation laws to solutions of simple two-dimensional dynamics problems.

EM 203 Mechanics of Materials 4R-0L-4C F,W Pre: EM 120

Strength and elastic deflection of engineering materials due to loads applied axially, in torsion, in bending, and in shear. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 204 Statics and Mechanics of Materials II 4R-0L-4C F,S Pre: EM 121

Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

EM 301 Fluid Mechanics 4R-0L-4C S Pre: EM 202

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

***EM403 Advanced Mechanics of Materials 4R-0L-4C S Pre: EM 203 or EM 204**

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

EM 406 Vibration Analysis 4R-0L-4C F Pre: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

Undergraduate-Graduate Courses

***EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Pre: ME401 or consent of instructor**

Course may be repeated for different topics in fluid mechanics.

***EM 502 Advanced Dynamics 4R-0L-4C Pre: ES 205**

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

***EM 503 Advanced Vibration Analysis 4R-0L-4C W Pre: EM 406**

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.

***EM 505 Theory of Elasticity 4R-0L-4C Pre: EM 203 or EM 204**

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

***EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Pre: EM 403 and MA 330**

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.

*May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors: Bunch, Ditteon, Duree, Granieri, Joenathan, Kirkpatrick, Kirtley, Lepkowicz, Letfullin, McInerney, Moloney, Siahmakoun, Syed, Wagner, and Western.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W Pre: PH113

Scaling laws in small systems, basics of quantum mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, nanomechanics, cantilever oscillation, atomic-force microscope (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors.

EP 290 Directed Study Credit arranged Pre: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S Pre: EP280

Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, nanoscale heat: conduction, convection, and radiation. Nanophotonics in metals and semiconductors, surface Plasmon resonance and applications, photonic bandgap crystals, basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise.

EP 408 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Same as ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Pre: EP 410 or equivalent course

Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Same as ME 419, ECE419, and CHE419.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

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Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

EP 415 Engineering Physics Projects I 4C S Pre: RH 330 and consent of the instructor

Team-oriented and/or independent design project work on selected topics in any engineering discipline but related to concepts to strengthen both the application and physics and engineering, design of project, building of prototype, experiments to test components and systems, and market analysis.

EP 416 Engineering Physics Projects II 4C F Pre: Consent of the instructor

Follow up course to EP415. To be taken as a sequence from the same department where EP415 was taken.

EP 417 Engineering Physics Projects III 2R-6L-4CW Pre: Consent of the instructor

Follow up course to EP416. To be taken as a sequence from the same department where EP415 and EP416 were taken.

EP 470 Special Topics in Engineering Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor.

EP 508 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Same as ME516, ECE516, CHE505, and BE516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Pre: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Same as ME 519, ECE 519, and CHE 519.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.



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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Mathematics

Professors Brooks, Broughton, K. Bryan, Butske, S. Carlson, Condori, M. DeVasher, Evans, Finn, Galinaitis, Graves, Grimaldi, Holden, A. Holder, L. Holder, Inlow, Jajcayova, Langley, Lautzenheiser, Leader, Rader, Rickert, Shibberu, and Su.

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Pre: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.

A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen. Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

MA 101 Introductory Calculus 5R-0L-2C F (5 weeks)

Covers approximately the first half of MA 111, including analytic geometry in the plane, algebraic and transcendental functions, limits and continuity, and an introduction to differentiation. Entering first-year students will enroll in MA 111 and transfer to MA 101 if continuation of MA 111 is not appropriate.

MA 102 Differential Calculus 5R-0L-3C W Pre: MA 101

Covers approximately the second half of MA 111, including the derivative, geometrical and physical applications of differentiation, and an introduction to integration and Fundamental Theorem of Calculus. Students who do not transfer to MA 101 in the fall quarter, but do not satisfactorily complete all of MA 111, may use their midterm grade in MA 111 for credit and grade in MA 101 and enter MA 102 at the beginning of the winter quarter.

MA 111 Calculus I 5R-0L-5C F

Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

MA 112 Calculus II 5R-0L-5C F,W,S Pre: MA 111 or 102

Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

MA 113 Calculus III 5R-0L-5C F,W,S Pre: MA 112

Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

MA 190 Contemporary Mathematical Problems 2R-0L-2C S co-requisite: MA 113

A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

applications, famous problems, and outstanding problems of great significance.

MA 200 Career Preparation 1R-0L-1C W,S

This course is for mathematics and biochemistry majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, PH200 and SV200.

MA 211 Differential Equations 4R-0L-4C F, W, S Pre: MA 113

First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F, W, S Pre: MA 113

Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F, W, S Pre: MA 112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,W Pre: MA 112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Pre: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arr Pre: CSSE 220 or CSSE221, and MA 212

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W, (odd years) Pre: MA 113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F Pre: MA 113

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F Pre: MA212

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of

linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA212 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C S Pre: MA 211, MA 212

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Pre: MA 211, MA 212

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA342 Computational Modeling 4R-0L-4C S Pre: MA332

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 348 Continuous Optimization 4R-0L-4C S (even years) Pre: MA 212

Optimization of nonlinear functions of real variables: algorithms for univariate optimization; Golden section, parabolic interpolation, hybrid methods; Newton's Method and variations for multivariate functions; conjugate gradients and quasi-Newton methods; line search strategies; penalty functions for constrained optimization; modeling and applications of optimization.

MA 351-6 Problem Solving Seminar 1R-0L-1C F, W, S Pre: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Pre: MA 275 and MA 113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Pre: MA 212

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Pre: MA 212 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. **A student cannot take both MA 371 and MA 373 for credit.**

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Pre: MA 212 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. **A student cannot take both MA 371 and MA 373 for credit.**

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Pre: MA 275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Pre: MA 275

An introduction to modern abstract algebra and algebraic structures. Topics include congruence and modular arithmetic; rings, ideals, and quotient rings; fields, finite fields, and subfields; groups and subgroups; homomorphisms and isomorphisms. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Pre: consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F, W, S Pre: MA 113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C (F) Pre: MA 381

This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the Central Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. **A student cannot take both MA 223 and MA 382 for credit.**

MA 383 Engineering Statistics II 4R-0L-4C F Pre: MA 223 or MA 382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Pre: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary.

MA 386 Statistical Programming 4R-0L-4C Pre: previous programming course and either MA 223 or MA 382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Pre: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 423 Topics in Geometry 4R-0L-4C (arranged) Pre: MA371 or MA373 or consent of instructor

An advanced course in geometry. Topics could include from projective geometry, computational geometry, differential geometry, Riemannian geometry, algebraic geometry, Euclidean geometry and non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 430 Topics in Applied Mathematics 4R-0L-4C (arranged) Pre: instructor permission

A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C (arranged) Pre: MA 330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to "direct methods." Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Pre: MA 212

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C (arranged) Pre: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Pre: MA 330

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green's function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Pre: MA212

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Pre: MA 212 or MA 371/373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development "from the ground up."

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Pre: MA 223 or MA 381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Pre: MA 375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F, W, S Pre: consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C (arranged) Pre: MA 366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C (arranged) Pre: MA 366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Pre: MA 371 or MA 373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Pre: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Pre: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C (arranged) Pre: MA 375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Pre: MA 375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Pre: MA 375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C (arranged) Pre: MA 378 or MA 375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Pre: CSSE 220 and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C (arranged) Pre: instructor permission

An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Pre: MA 382, or MA 381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-OL-4C S Pre: MA 223 or MA 382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-OL-4C W (odd years) Pre: MA 212 and either MA 223 or MA 382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-OL-4C W (even years) Pre: MA 223 or MA 382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics, variable credit, Pre: consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Pre: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Pre: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F, W Pre: MA 492 or permission of the instructor

MA 494 Senior Project III 2C W, S Pre: MA 493

Participation in sponsored projects or problems with a substantial mathematical and/or computational content. Students typically work in teams of at most 3, with appropriate faculty supervision. Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of Senior Project must be completed in a form acceptable to the sponsor and the advisor.

MA 495 Research Project in Mathematics, variable credit, Pre: consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Pre: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Pre: MA 496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Pre: MA 497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

MA 580 Topics in Advanced Probability Theory and Its Applications 4R-0L-4C (arranged) Pre: MA 381

Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-0L-4C (arranged) Pre: MA 223 or MA 381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Pre: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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Mechanical Engineering

Professors Adams, Brackin, Burchett, Chambers, Cornwell, Cunningham, Fine, Fisher, Gibson, Haan, Layton, Lui, Mayhew, Mech, Moorhead, Moseley, Olson, Onyancha, Purdy, Richards, Sanders, Stamper, Stienstra, Toohey, and White.

ME 123 Computer Applications I 4R-0L-4C W,S Pre: None

Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion (Working Model), presentation software (Powerpoint, HTML), and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S

Selected student design projects. May include testing and/or computer aided design.

ME 201 Thermodynamics I 4R-0L-4C F Pre: MA 112

Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Sophomore class standing

Selected student design projects. May include testing and/or computer aided design.

ME 301 Thermodynamics II 4R-0L-4C F,W Pre: ES 202 or ME 201

Applies property and component background to the analysis of various power and refrigeration cycles. Presents gas and gas-vapor mixtures, psychometric processes, and combustion. Introduces compressible flow.

ME 302 Heat Transfer 4R-0L-4C S,F Pre: MA 211 and ES 202 or CHE 301 or EM 301

Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Pre: ES 202

Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Pre: EM 104

This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Pre: ME 328

An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Pre: ECE 207, ES 205, MA 223

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Computer Applications II 1R-3L-2C W,S Pre: ME 123, MA 212

Introduction to structured programming and applied numerical methods in scientific computing. The course uses applied problems in engineering and mathematics to introduce numerical methods such as numerical interpolation, finite differencing, integration, root finding, and linear algebraic system solutions. Matlab is taught as a vehicle for solving the problems numerically in a structured high speed environment.

ME 328 Materials Engineering 4R-0L-4C W Pre: CHEM 111 or CHEM 201 or CHEM 105

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Pre: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in "on-the-spot" design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

***ME 401 Foundation of Fluid Mechanics 3R-3L-4C Pre: ES 202 or EM 301, MA 212**

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective*

***ME 402 Advanced Heat Transfer 4R-0L-4C Pre: ME 302**

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 403 Kinematics of Machinery 4R-0L-4C Pre: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

***ME 405 Theoretical Aerodynamics 4R-0L-4C F Pre: ES 202**

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace's equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 406 Control Systems 3R-3L-4C F Pre: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Pre: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are

taken when available.

ME 408 Renewable Energy 4R-0L-4C Pre: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C F Pre: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Pre: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Pre: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Pre: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

***ME 417 Advanced Materials Engineering 4R-0L-4C Pre: ME 328 and EM 203 or EM 204**

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Pre: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

***ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Pre: Junior class standing**

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Pre: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Pre: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Pre: ES 205 and ES 202 or equivalent

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

***ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Pre: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 430 Mechatronic Systems 3R-3L-4C F,W Pre: (ME 323 or CSSE 220 or ECE 230) and (ECE 207 or ECE 204) or consent of instructor

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

***ME 435 Robotics Engineering 3R-3L-4C S Pre: ME 430 and Senior class standing**

Interdisciplinary course in engineering systems applied to computer controlled automata. Topics include kinematics, control, operation, sensing, and design as applied to various types of industrial and other robots and programmable manipulators. A related project is required.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 461 Aircraft Design 4R-0L-4C W Pre: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams. Can be taken in lieu of ME 460, Machine Design or ME 462, Thermal Design.

ME 462 Thermal Design 4R-0L-4C W,S Pre: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Engineering Design Processes and Methodology 2R-3L-3C F,S Pre: 3rd qtr junior standing

Design of multi-component systems with consideration of societal and economic factors. Useful design techniques (such as modeling, CPM, optimization, probabilistic approaches, etc.) and factors influencing design (such as human factors, products liability, ethics, safety, etc.) are presented and discussed. Laboratory assignments emphasize case studies. (Students completing ME470 may not receive credit for EMGT 461.)

ME 471 Capstone Design I 1R-6L-3C W Pre: ME 470, ME 480

Design projects with industry. Students work in teams with three or four members on design projects furnished from external clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in oral presentations and Interim Written Reports which are submitted to the clients.

ME 472 Capstone Design II 1R-6L-3C S Pre: ME 471

This course is a continuation of ME 471. The student teams continue their design solutions to a general problem furnished by an external client. Continuous and regular communication with the outside clients is expected, as well as with the faculty advisors. During these ten weeks the teams continue refining their solutions, complete the detail design, make oral presentations of the final design, and complete and submit the Final Written Report.

ME 480 Machine Component Design 4R-0L-4C S & F Pre: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor
Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Senior class standing
Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged
Topics of current interests in mechanical engineering.

NOTE: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

***ME 501 Advanced Thermodynamics 4R-0L-4C F Pre: ME 301 or equivalent**
Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Pre: ME 302**
Course may be repeated for different heat transfer topics.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 503 Viscous Fluid Flow 4R-0L-4C Pre: ME 401**
Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Pre: ES 205, MA 212**
Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 506 Advanced Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**
Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 507 Applied Nonlinear Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**
Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liaqunov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 510 Gas Dynamics 4R-0L-4C F Pre: ES 202**
Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..

***ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Pre: ES 205 and ME 323**
Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 512 Light Weight Structures 4R-0L-4C S Pre: MA 212 and EM 203 or EM 204**

Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 513 Environmental Noise 4R-0L-4C F Pre: Senior class standing**

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Students enrolled in EP510, ME516, ECE516, CHE505, BE516 must do project work on a topic selected by the instructor.

***ME 518 Advanced Kinematics 4R-0L-4C S Pre: ME 303**

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

Students enrolled in EP511, ME519, ECE519, CHE519, BE516 must do project work on a topic selected by the instructor.

***ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Pre: EM 104 and Senior class standing**

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 522 Advanced Finite Element Analysis 4R-1L-4C S Pre: ME 422**

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 590 Thesis Research F,W,S**

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 597 Selected Topics for Graduate Students. Credits as assigned.** Maximum 4 credits per term. F,W,S

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..



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Course Descriptions

CATALOG HOME

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

Military Science (Army ROTC)

LTC Peffers, MAJ Ikenberry

Freshman Year Basic Course

MS 101: Leadership and Personal Development 1R-3L-1C F Pre : None

MS 101 introduces cadets to the personal challenges and competencies that are critical for effective leadership. Cadets learn how the personal development of life skills such as critical thinking, goal setting, time management, physical fitness, and stress management relate to leadership, officership, and the Army profession. The focus is on developing basic knowledge and comprehension of Army leadership dimensions while gaining a big picture understanding of the ROTC program, its purpose in the Army, and its advantages for the student.

MS 102: Introduction to Tactical Leadership 1R-3L-1C W Pre: MS 101 or Instructor Permission

MS 102 overviews leadership fundamentals such as setting direction, problem-solving, listening, presenting briefs, providing feedback, and using effective writing skills. Cadets explore dimensions of leadership values, attributes, skills, and actions in the context of practical, hands-on, and interactive exercises. Continued emphasis is placed on recruitment and retention of cadets. Cadre role models and the building of stronger relationships among the cadets through common experience and practical interaction are critical aspects of the MS 102 experience.

MS 103: Basic Tactical leadership 1R-3L-1C S Pre: MS 101 and 102 or Instructor Permission

MS 103 continues the exploration of leadership fundamentals and examines the leadership process as affected by individual differences and styles, group dynamics, and personality behavior of leaders. Students will experience an introduction of fundamental leadership concepts, and examine factors that influence leader and group effectiveness. Students will fully explore the basic soldier skills and squad level tactical operations. Students participate in briefings and hands-on practical exercises. Attention is devoted to development of leadership potential through practical exercises both in and out of the classroom.

Sophomore Year Basic Course

MS 201: Innovative Team Leadership 2R-3L-2C F Pre: MS 101, 102, and 103 or Instructor Permission

MS 201 explores the dimensions of creative and innovative tactical leadership strategies and styles by examining team dynamics and two historical leadership theories that form the basis of the Army leadership framework. Cadets practice aspects of personal motivation and team building in the context of planning, executing, and assessing team exercises and participating in leadership labs. Focus is on continued development of the knowledge of leadership values and attributes through an understanding of Army rank, structure, and duties and basic aspects of land navigation and squad tactics. Case studies provide tangible context for learning the Soldier's Creed and Warrior Ethos as they apply in the contemporary operating environment (COE).

MS 202: Foundations of Tactical Leadership 2R-3L-2C W Pre: MS 201 or Instructor Permission

MS202 examines the challenges of leading tactical teams in the COE. The course highlights dimensions of terrain analysis, patrolling, and operation orders. Further study of the theoretical basis of the Army leadership framework explores the dynamics of adaptive leadership in the context of military operations. Cadets develop greater self awareness as they assess their own leadership styles and practice communication and team building skills. COE case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

College & Life Skills

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Pre: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Leaders' Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Leaders' Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

Junior Year Advanced Course

MS 301: Adaptive Team Leadership 3R-3L-4C F Pre: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 challenges cadets to study, practice, and evaluate adaptive leadership skills as they are presented with challenging scenarios related to squad tactical operations. Cadets receive systematic and specific feedback on their leadership attributes and actions. Based on such feedback, as well as their own self-evaluations, cadets continue to develop their leadership and critical thinking abilities. The focus is developing cadets' tactical leadership abilities to enable them to succeed at ROTC's summer Leadership Development and Assessment Course (LDAC).

MS 302: Leadership Under Fire 3R-3L-4C W Pre: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when "under fire" are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Leader Development and Assessment Course (LDAC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Pre: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for LDAC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

**Overview of LDAC: Leader Development and Assessment Course
Summer Term Only**

LDAC/Warrior Forge is the crucible of the Army ROTC Program. As such, Cadet Command must provide the best professional training and evaluation possible for all cadets. The primary focus at LDAC is to evaluate each cadet's officer potential in a collective environment. The secondary purpose of LDAC is to validate specific skills taught on campus and to impart selective individual and collective common skills. LDAC represents the only opportunity for this command to assemble cadets from disparate schools into an environment with common operational conditions.

Senior Year Advanced Course

MS 401: Developing Adaptive Leaders 3R-3L-4C F Pre: MS 303

MS 401 develops cadet proficiency in planning, executing, and assessing complex operations, functioning as a member of a staff, and providing performance feedback to subordinates. Cadets assess risk, make ethical decisions, and lead fellow ROTC cadets. Lessons on military justice and personnel processes prepare cadets to make the transition to Army officers. Cadets analyze, evaluate, and instruct cadets at lower levels. Both their classroom and battalion leadership experiences are designed to prepare cadets for their first unit of assignment. They identify responsibilities of key staff, coordinate staff roles, and use situational opportunities to teach, train,

and develop subordinates.

MS 402: Leadership in a Complex World 3R-3L-4C W Pre: MS 401

MS 402 explores the dynamics of leading in the complex situations of current military operations in the COE. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. They also explore aspects of interacting with nongovernmental organizations, civilians on the battlefield, and host nation support. The course places significant emphasis on preparing cadets for their first unit of assignment. It uses case studies, scenarios, and "What Now, Lieutenant?" exercises to prepare cadets to face the complex ethical and practical demands of leading as commissioned officers in the United States Army.

MS 403: Leadership in a Complex World II 3R-3L-4C S Pre: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Pre: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Optical Engineering

Professors: Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, Kirtley, Lepkowicz, Letfullin, McInerney, Moloney, Siahmakoun, Syed, Wagner, and Western.

Note: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

OE 171 Photography and Holography 2R-OL-2C F
Introduce students to basic knowledge of optics, principles and operation of a camera, shutters, films, and film development, color photography. Basic understanding of interference of waves, concept of holography, properties of various holograms, application of holography, and each student makes an individual hologram that can be seen in sunlight.

OE 172 Optics in Technology 2R-OL-2C S
Introduction to the properties of lasers; types of lasers; characteristics of optical fibers, optical communication, applications of lasers and fibers in industry, medicine and commercial products; fundamentals of holography, applications in art and industry.

OE 280 Paraxial Optics 3.5R-1.5L-4C W Pre: PH 113
First order geometrical optics including image formation, y-nu ray tracing, cardinal points, stops and apertures, matrix methods and an introduction to optical instruments. Introduction to computer-aided analysis.

OE 290 Directed Research Credit arranged Pre: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 295 Optical Systems 3.5R-1.5L-4C S Pre: PH 113 and MA 211
Components of optical systems; introduction to lasers light and Gaussian beams; optical fibers; fiber optic systems; radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; noise in detectors; CCD arrays, optical instruments.

OE 360 Optical Materials and Opto-Mechanics 4R-OL-4C F Pre: OE 295
Optical properties of materials, optical coatings, principles of opto-mechanical design, fold mirrors and prisms, tolerancing, specifications of optical components, lens and mirror mounting, kinematics systems, precision adjustments and control.

OE 392 Wave Optics & Coherence 4R-OL-4C Arranged Pre: PH 292, MA 212
Propagation of light, Fresnel equations; Fraunhofer and Fresnel diffraction; coherence; Fourier transforms, convolution and correlation; optical transfer function (OTC), modulation transfer function (MTF); speckles; holography, moire.

OE 393 Fiber Optics and Applications 3R-3L-4C W Pre: OE 295, PH 316 or ECE 341 or consent of instructor
Basic dielectric waveguide equations; wave optics and ray optics; step-index and graded-index fibers; single mode and multi-mode fibers; mode cutoff conditions; numerical aperture; fabrication of optical fibers; fiber measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic

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- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

components and systems.

OE 395 Optical Instrumentation 3R-3L-4C Arranged Pre: OE 280 and PH 292

Radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; signal conditioning and noise; CCD arrays; optical instruments; color; selected experiments on the application of optical instruments.

OE415 Optical Engineering Design I 2R-6L-4C S Pre: OE 295 Coreq: RH330 or consent of the instructor

Principles of design. Codes of ethics appropriate to optical engineers. Case studies related to optical engineering professional practice, teamwork, contemporary issues, patents and intellectual property. Team oriented design project work on selected topics in optical engineering. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints.

OE416 Optical Engineering Design II 2R-6L-4C F Pre: OE 415

Design project, system-level design and detail design. Construction of a prototype product. Product development economics, costs and market research. Testing optical components and systems, electronic systems, optical measurement tools, mechanical measurements, opto-mechanics, and opto-electronics.

OE417 Optical Engineering Design III 2R-6L-4C W Pre: OE416

Continuation of OE416 design project. Delivery of a functional prototype product. Complete product development documentation including a technical report, design documents, product design specification, drawings, acceptance test document, project plan. Oral presentation.

OE 435 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 212, and SR/GR standing

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications. Same as BE 435.

OE 450 Laser Systems and Applications 3R-3L-4C S Pre: PH 292 and MA 212 or JR standing or consent of instructor

Laser safety; Gaussian beam propagation; cavity design; longitudinal and transverse modes; stimulated emission; population inversion; rate equations; gain and threshold; Q-switching and mode-locking; types of laser systems; laser applications in communication; medicine, military, and industry.

OE 470 Special Topics in Optical Engineering 2-4 Credits Pre: Consent of instructor

Lectures on special topics in optics.

OE 480 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 Coreq: OE 360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, y-y bar diagrams as a design tool, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Introduction to computer-aided design, design of optical systems including camera lenses, mirror systems and catadioptric systems.

OE 485 Electro-Optics and Applications 3R-3L-4C W Pre: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, electro-optic effect in liquid crystals, photorefractive effect, acousto-optic effect and modulators, second-harmonic generation, optical phase-conjugation and applications.

OE 490 Directed Research Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3R-3L-4C F Pre: OE393, ECE310 or graduate standing or consent of the instructor

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Soliton propagation. Relevant laboratories

OE 495 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); review of interference and coherence; fringe visibility; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Pre: OE 295, PH 292, PH 316 or SR/GR standing or consent of instructor

Classical optics; exact ray tracing; aberrations, interference, polarization, spatial and temporal coherence; lasers and Gaussian beam propagation; diffraction; optical sources and detectors; selected applications of optics.

OE 535/BE 535 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 212 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications. For graduate credit, students must do additional project work on a topic selected by the instructor.

OE 570 Special Topics in Optics 2 or 4C F,W,S Pre: OE 295, PH 292, and PH 316

Lectures on special topics in optics such as: optical materials, optics of thin films and infrared optics.

OE 580 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, y y bar diagrams as a design tool, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Introduction to computer aided design, design of optical systems including camera lenses, mirror systems and catadioptric systems. For graduate credit, students must do additional project work on a topic selected by the instructor.

OE 585 Electro Optics and Applications 3R-3L-4C W Pre: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, electro-optic effect in liquid crystals, photorefractive effect, acousto-optic effect and modulators, second-harmonic generation, optical phase-conjugation and applications. For graduate credit, students must do additional project work on a topic selected by the instructor.

OE 592 Fourier Optics and Applications 3R-3L-4C F Pre: SR/GR standing or consent of instructor

Two-dimensional linear systems; diffraction theory (Fresnel & Fraunhofer); imaging properties of lenses; frequency analysis of optical imaging systems; spatial filtering; optical information processing; Vander-Lugt filters; wavefront reconstruction; holography; optical computing.

OE 593 Fundamentals of Optical Fiber Communications 3R-3L-4C S

Pre: OE393 or graduate standing or consent of the instructor

Evolution of fiber optics links and networks: information rate, evaluation of fiber optic systems, optical fiber transmission link. Digital transmission systems: point-to-point links, line coding, error correction. Analog systems: links, dynamic range, noise figure, bandwidth, carrier-to-noise, multi-channel transmission, cross talk. WDM concepts: operational principles, passive components, system considerations. Optical networks: network topologies, performance of linear bus, performance of star architecture, SONET, WDM networks, wavelength-routed networks, optical CDMA, ultra high capacity WDM networks, bit-interleaved optical TDM, time-slotted optical TDM.

Students enrolled in OE593 must do project work on a topic selected by the instructor.

OE 594 Guided-Wave Optics 3R-3L-4C S Pre: OE 485 or SR/GR standing or consent of instructor

Theory of optical waveguides; waveguide modes; fabrication techniques; input and output coupling techniques; waveguide losses; waveguide gratings; electro-optic modulators; integrated optical detectors; applications of integrated optics.

OE 595 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-

Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); review of interference and coherence; fringe visibility; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Students must do additional project work on a topic selected by the instructor.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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Academics

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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Physics

Professors: Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, Kirtley, Lepkowicz, Letfullin, McInerney, Moloney, Siahmakoun, Syed, Wagner, and Western.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

PH 111 Physics I 3.5R-1.5L-4C F, W Coreq: MA 111
Kinematics, Newton's laws of motion, gravitation, Coulomb's law, Lorentz force law, strong and weak nuclear forces, conservation of energy and momentum, relevant laboratory experiments.

PH 112 Physics II 3.5R-1.5L-4C W, S Pre: PH 111 and MA 111; Co: MA 112
Torque and angular momentum, oscillations, one-dimensional waves, electric fields and potentials, electric current and resistance, DC circuits, capacitance, relevant laboratory experiments.

PH 113 Physics III 3.5R-1.5L-4C S, F Pre: PH 112 and MA 112; Coreq: MA 113
Sources of magnetic fields, Faraday's law, inductance electromagnetic waves, reflection and polarization, geometric and physical optics, introduction to relativity, relevant laboratory experiments.

PH 200 Career Preparation 1R-0L-1C W,S
This course is for physics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. This course is cross-listed with CHEM200, MA200 and SV200.

PH 215 Introduction to CHAOS 2R-0L-2C W
What constitutes chaotic behavior, detection of chaos in real systems using phase space plots, Poincare sections, bifurcation plots, power spectra, Lyapunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Pre: MA 111, and PH 111 or EM 120
Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Pre: PH 111 or Coreq: EM 202; and Coreq: MA 112
Dynamics of rigid body, harmonic motion; mechanics of fluids; heat, kinetic theory, thermodynamics. Alternate week laboratories.

PH 241 Physics of Stars 4R-0L-4C W Pre: MA 111, and PH 111 or EM 120
Binary stars and stellar parameters; stellar spectra; stellar atmospheres; stellar interiors; star formation; stellar evolution; star death; stellar remnants; black holes and binary stars.

PH 250 Planets and Galaxies 4R-0L-4C S Pre: MA 111, and PH 111 or EM 120
Overview of planets and planetary science; origin and evolution of the solar system; structure and evolution of galaxies; origin and evolution of the universe; introduction to cosmology.

PH 255 Foundations of Modern Physics 3.5R-1.5L-4C W Pre: PH 113 and Coreq: MA 211
Wave-particle nature of matter and radiation, Bohr model, Schrodinger equation, quantum description of the hydrogen atom, atomic and molecular spectra, and introduction to statistical physics.

- Aerospace Studies (Air Force ROTC)
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- Chemical Engineering
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- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

PH 265 Fundamentals of Nuclear Physics and Radiation 3R-3L-4C S Pre: PH 112, and MA 211

Relativity, black-body radiation, the Bohr model, physics of the nucleus, fission and fusion, reactors, nuclear radiation, radiation damage, medical applications.

PH 270 Special Topics in Physics Credit arranged Pre: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Pre: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Pre: PH 113

Electromagnetic waves; interference; optical interferometry; coherence; polarized light; Jones vec-tors/matrices; production of polarized light; birefringence, Fraunhofer diffraction, diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Pre: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Pre: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S, Arranged Pre: PH 111, PH 235, MA 212

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W, Arranged Pre: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Pre: PH 113, MA211, and MA 212

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Pre: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Pre: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Pre: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication, transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Pre: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 330 Material Failure 3R-3L-4C W Pre: PH 113

Physical principles of instrumentation used for material failure analysis, including light microscopy, electron microscopy, and spectroscopy. Laboratory includes experiments and case studies using these instruments.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Pre: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schroedinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schrodinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Pre: PH 113, and MA 212

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films.

PH 407 Solid State Physics 4R-0L-4C S (even years) Pre: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Pre: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Pre: MA 212, and JR/SR or Graduate standing

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory.

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Pre: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Pre: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit 1-2 C Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 2 credits per term. The student must make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Pre: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Pre: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Pre: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.



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Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Robotics

ROBO 410 Robotics Capstone Design I 1R-6L-3C F
Pre for EE or CPE: ECE 362, and a co-requisite ME 430
Pre for ME: ME senior class standing, and co-requisites of ME 430 and ME 470
Pre for CS or SE: RH 330 and CSSE 374, and a co-requisite ME 430

ROBO 420 Robotics Capstone Design II 1R-6L-3C W
Pre: ROBO 410

ROBO 430 Robotics Capstone Design III 1R-6L-3C S
Pre: ROBO 420

Description: Interdisciplinary group robotics engineering project. This requires the carrying out, from inception to completion, of a robotics-related system development for an approved client. The focus for students from each major is on design appropriate to that major related to robotics. Teamwork activities are expected to involve coordination of multidisciplinary aspects of the project, team planning, leading, and reviewing of project progress versus risks. Engineering practices related to design include requirements and constraint analysis and management, design creation and documentation, prototyping, system construction and testing, following of engineering standards, and management of intellectual property. Technical completion and delivery to the client is expected.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- College & Life Skills
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
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- Physics
- Robotics
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Sophomore Engineering

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit Hours

- MA 221 Differential Equations & Matrix Algebra I (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit Hours

- MA 222 Differential Equations & Matrix Algebra II (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER 8 Credit Hours

- MA 223 Statistics for Engineers (4)
- ES 205 Analysis and Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- Develop a strong background in engineering science,
- Develop an understanding of modeling,
- Be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- Continue to develop effective communication skills,
- Be proficient in applying standard statistical procedures and quality control concepts,
- Develop a strong background in mathematics,
- Be encouraged to be inquisitive and self-motivated learners,
- Develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,
- Be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- Be able to apply computer tools appropriately,
- Be comfortable working with ambiguity,
- Be familiar with the overall design process,
- Be able to locate and retrieve both technical and non-technical information,
- Be introduced to safe and effective use of instruments,
- Appreciate the role of creativity in engineering,

Aerospace Studies (Air Force ROTC)
Applied Biology & Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Military Science (Army ROTC)
Multi-Disciplinary Studies
Optical Engineering
Physics
Robotics
Sophomore Engineering

- Develop a recognition of the benefits of the new curriculum, and
- Be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Pre: MA 113, PH 111

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid & Thermal Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better

Conservation and accounting equations applied to fluid and thermal systems. Fluid and thermodynamic properties of pure substances. Open and closed systems hydrostatics. Dimensional analysis. Mechanical energy balance and pipe flow. Lift and drag.

ES 203 Electrical Systems; 3R-3L-4C; F,W,S; Pre: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better Co: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Pre: ES 202, ES 203 with a grade of C or better, OR ECE 203 with a grade of C or better, ES 204, MA 211

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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News

Calendars

Alumni

Athletics

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Entrepreneurship Minor

Programs - Entrepreneurship Minor

Increasing globalization and the need for rapid implementation of innovations mean that that 21st Century engineers and scientists need to think like entrepreneurs. Everyone does not have to start a technology based business, but understanding the requirements of technology commercialization needs to be part scientific and technical thinking.

The Engineering Management Program has new programs in entrepreneurship for everyone to consider. These are intended to provide the basic tools for making new technology commercially successful.

The requirements of the undergraduate minor are 20 credits of the following:

- EMGT 427 Project Management
 - SV 350 Managerial Accounting
 - SV 356 Corporate Finance
 - IA 453 The Entrepreneur
 - IA 498 Technology Management & Forecasting
- or
- EMGT 423 Intro to Marketing for Technical Products

Up to 12 credits of EMGT 461, 462 and 463 may be substituted for the classes above. Other substitutions may be made with the approval of the head of the engineering management department. No more than one course may be transferred in to count toward the minor.

Participation in an entrepreneurial senior design experience approved by the head of the Engineering Management Department. This may be a part of the student's departmental design course, as well as participation in the Multidisciplinary, Entrepreneurial Design sequence

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Map and Directions

Employment

Accessibility

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INSTITUTE OF TECHNOLOGY

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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Applied Biology

Programs - Applied Biology

The twenty-first century will see unparalleled advances in the biological sciences. Disciplines such as applied biology and biomedical engineering are burgeoning and will greatly impact the way we live in the future. The areas of functional genomics and proteomics will drive discoveries in molecular medicine, gene therapy and tissue engineering. Drug discovery will be facilitated by the elucidation of new target molecules and many pharmaceutical compounds will be produced using biological processes. Environmental management, remediation and restoration will also benefit from advances in applied biology. Biologists will be at the forefront of these advances and will drive the medical, agricultural, environmental and industrial applications of biological sciences.

The applied biology program will produce biologists with the chemistry, mathematics, and physics background needed to solve biotechnological problems in the coming decades. Those students wishing to strengthen their engineering skills can earn the area minor in biomedical engineering. Other students may choose to pursue a second major in [Biochemistry and Molecular Biology](#). The program will prepare graduates for professional careers in government and industrial research laboratories, and in the biotechnology and health-related industries.

Those wishing to continue their studies in graduate or health professions programs will be exceptionally well qualified to do so.

APPLIED BIOLOGY PLAN OF STUDY

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
AB	110	Cell Structure and Function	4	AB	210	Mendelian & Molecular Genetics.....	4
CHEM	111	General Chemistry I.....	4				
MA	111	Calculus I.....	5	CHEM	251	Organic Chemistry I.....	4
CLSK	100	College & Life Skills.....	1	PH	111	Physics I.....	4
			14	MA	221	Differential Equations I.....	4
							16
Winter Term				Winter Term			
			Credit				Credit
AB	120	Comparative Anatomy & Physiology.....	4	AB	220	Prokaryotic Cell & Molecular Biology.....	4
CHEM	113	General Chemistry II.....	4				
MA	112	Calculus II.....	5	CHEM	252	Organic Chemistry II.....	4
BE	100	Problem Solving in the Biological Sciences and Engineering.....	4	PH	112	Physics II.....	4
				HSS		Elective	4
							16

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

17				Spring Term				Credit	
Spring Term									
								Credit	
AB	130	Evolution and Diversity...	4	AB	230	Eukaryotic Cell & Molecular Biology.....		4	
CHEM	115	General Chemistry III.....	4	CHEM	253	Organic Chemistry III.....		4	
MA	113	Calculus III.....	5	PH	113	Physics III		4	
RH	131	Rhetoric & Composition ...	4	MA	223	Engineering Statistics.....		4	
17								16	
Junior Year				Senior Year					
Fall Term				Fall Term				Credit	
AB	320	Ecology.....	4	AB	499	Thesis Research.....		4	
		Free elective.....	4			Science/Technical		4	
AB		Elective	4			Elective			
RH	330	Technical and Professional Communication		HSS		Elective.....		4	
		or				Free elective.....		4	
HSS		Elective	4					16	
AB	301	Jr. Colloq.	1						
17				Winter Term				Credit	
Winter Term									
AB	330	Evolutionary Biology.....	4	AB	401	Senior Colloquium.....		2	
CHEM	330	Biochemistry.....	4			Science/Technical		4	
AB		Elective.....	4			Elective			
HSS		Elective		AB	499	Thesis Research.....		4	
		or		HSS		Elective.....		4	
RH	330	Technical and Professional Communication	4					14	
AB	302	Junior Colloquium.....	1	Spring Term				Credit	
17									
Spring Term									
AB	310	Plant Structure & Function.....	4					12	
AB	499	Thesis Research.....	4						
SV	304	Bioethics.....	4						
HSS		Elective.....	4						
16									

Total credits required: 188

An AB science/technical elective is any Rose-Hulman course that has a prefix of AB, BE, CHEM, CHE, CE, CSSE, ECE, MA, ME, PH, OE, EP, ES, EM or any EMGT course that is not cross-listed with an RH, GS, IA or SV course. Courses that do not count as science or technical electives are those courses with AS, MS, RH, GS, IA, SV, GE, JP, SP, FL, GRAD and CLSK prefixes.

SUMMARY

Required AB courses	52 credits
AB electives	12 credits
Free electives	8 credits
HSS electives	24 credits
Required HSS	12 credits
Required MA, CHEM, PH	63 credits

Required CLSK	1 credits
Sci/Tech electives	12 credits
Required BE course	4 credits

Total **188 credits**

Biochemistry & Molecular Biology (Second Major Only)

The biochemistry & molecular biology program exists to give students an opportunity to augment their education in this technologically-important field. To support this effort, Rose-Hulman provides students with access to a modern and well-equipped biochemistry lab, along with an excellent biological sciences facility. Two faculty are directly involved with this program: Dr. Mark Brandt, assistant professor of chemistry, is the program coordinator and is a biochemist, and Dr. Richard Anthony, associate professor of applied biology, is a molecular biologist. Many other faculty in both the chemistry and applied biology departments assist with this curriculum.

Biochemistry & molecular biology is available to Rose-Hulman students as a second major. This means that the student will receive a first degree in some other discipline and then can augment their education with this program. Students whose first degree programs are in chemistry or chemical engineering will find the program easiest since there is considerable overlap between those programs and the biochemistry & molecular biology requirements. Students from other disciplines are also encouraged to participate, but will have to take more courses. All students are encouraged to take individual courses in the program, regardless of whether or not they wish to fulfill the second major requirements, or to participate in related research projects under faculty supervision.

Two degree or double major programs in Biochemistry & Molecular Biology and Biochemistry are not allowed.

Required courses:

Course	Description	Hours
CHEM 111, 113, 115	General Chemistry	12
CHEM 251, 252, 253	Organic Chemistry	12
CHEM 330, 430, 433	Biochemistry	9
CHEM 361, 362 or CHEM 360 and CHE 303, 304	Physical Chemistry	8
AB 110, 120, 130	Biology	12
AB 210	Genetics	4
AB 220, 230	Molecular Biology	8
AB 411	Genetic Engineering	4
Total		69

ELECTIVE COURSES

Choose 12 credits* from the following courses:

AB 330	Evolutionary Biology
AB 421	Applied Microbiology
AB 431	Genomics and Proteomics
AB 441	Virology
AB 451	Cancer Biology
AB 492	Directed Study in Applied Biology

CHEM 225	Analytical chemistry
CHEM 291	Introduction to Research
CHEM 331	Biochemistry II
CHEM 431	Biochemical Instrumentation
CHEM 451	Organic Structure Determination
CHEM 290	Chemical Research

Or

CHEM 490

PH 302 Biophysics

Total Credits for second major	81
---------------------------------------	-----------

*Students with a major in chemistry need to take 8 credits of electives, with 4 credits from the AB electives listed, and 4 credits chosen from any AB or BE course.

STUDENTS WITH A MAJOR IN APPLIED BIOLOGY must take 12 credits of electives, with 8 credits from the elective courses listed above with a CHEM prefix, and 4 credits from any 300 level or above AB course (total: 29 hours required beyond Applied Biology major).

Applied Biology Area Minor

The Area Minor in Applied Biology is designed to allow students to enrich studies in their major area. Students wishing to apply another science, mathematics, or engineering discipline to investigate or solve problems in biological systems are encouraged to pursue the Area Minor in Applied Biology. With proper course selection, the Area Minor will provide another marketable dimension to any Bachelor of Science degree granted by the Institute.

The Area Minor in Applied Biology has the following requirements.

1. All students must complete AB110 (Cell Structure and Function) or AB130 (Evolution and Diversity) and at least four more courses in applied biology (AB) or allied areas, above those courses already specifically required to fulfill the student's major.
 - a. At least three of the four electives must be AB courses.
 - b. At least three of the electives must be 200-level or above.

Additional courses not listed in the approved allied areas can be considered on a case-by-case basis.
See ABBE Department Head.
2. Students electing to pursue the Area Minor in Applied Biology must follow a plan of study that is approved by the Area Minor Advisor. Current advisor information and a form for the planning and approval of an area minor can be obtained from the ABBE Department secretary.
3. Allied area courses could include:
 - o BE 310 Analysis of Physiological Systems
 - o IBE 320 Analysis of Physiological Systems II
 - o BE/MA 482 Bioengineering Statistics
 - o BE 570 Introduction to Tissue Engineering
 - o CE 460 Introduction to Environmental Engineering
 - o CHE 545 Introduction to Biochemical Engineering
 - o CHEM 264 Environmental Chemistry
 - o CHEM 330 Survey of Biochemistry
 - o CHEM 430 Advanced Biochemistry
 - o PH 302 Biophysics
 - o SL 386 Human Evolution
 - o VA 373 Gender Issues

Biochemistry & Molecular Biology Area Minor

Completion of AB110, CHEM111, CHEM113 and CHEM115 or AB110, CHEM105 and CHEM107. In addition, the student must complete five courses from the following list that are not already named required courses by the student's major or minor programs:

AB210 - Mendelian and Molecular Genetics
AB220 - Prokaryotic Cell and Molecular Biology
or

AB230 - Eukaryotic Cell and Molecular Biology
AB411 - Genetic Engineering or AB431 - Genomics and Proteomics
CHEM230 - Introduction to Organic Chemistry and Biochemistry
or
CHEM251 - Organic Chemistry I and CHEM252 - Organic Chemistry II
CHEM330 - Biochemistry
CHEM430 - Advanced Biochemistry with the CHEM433 Biochemistry Laboratory



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Biochemistry

Programs - Biochemistry

Graduates with a degree in biochemistry will be well prepared for employment, graduate study in biochemistry or other chemistry-related fields, or professional school. Biochemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in biochemistry, medicinal chemistry, and in other life science fields. A biochemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry along with biochemistry and applied biology. Students have access to modern instrumentation along with a well-equipped biochemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

BIOCHEMISTRY PLAN OF STUDY

Freshman Year				Sophomore Year			
Fall Term				Fall Term			
			Credit				Credit
CHEM	111*	General Chemistry I.....	4	CHEM	251	Organic Chemistry I	4
MA	111	Calculus I	5	PH	113	Physics III.....	4
AB	110**	Cell Structure & Function...	4	MA	221	Differential Equations &	
CLSK	100	College and Life Skills	1			Matrix Algebra I.....	4
RH	131	Rhetoric and Composition		AB	210	Mendelian & Mol	
		or				Genetics.....	4
HSS		Elective.....	4				
			18				16
Winter Term				Winter Term			
			Credit				Credit
CHEM	113*	General Chemistry II	4	CHEM	252	Organic Chemistry II	4
MA	112	Calculus II.....	5	CHEM	291	Intro to Undergraduate	4
PH	111	Physics I.....	4			Research.....	
RH	131	Rhetoric & Composition		MA	223*	** Engineering Statistics I	4
		or				Or MA 381	
HSS		Elective.....	4	AB	220	Prokaryotic Cell & Mol. Biology	4
			17				16
Spring Term							

- Applied Biology
- Biochemistry
- Biomedical Engineering
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- Electrical Engineering
- Engineering Physics
- Mathematics
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- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Spring Term					Credit			Credit	
						CHEM	253	Organic Chemistry III	4
CHEM	115	General Chemistry III	4			CHEM	225	Analytical Chemistry	4
MA	113	Calculus III.....	5			AB	230	Eukaryotic Cell & Mol.	
PH	112	Physics II.....	4					Biology.....	4
HSS		Elective.....	4					Free Elective.....	4
			<u>17</u>					<u>16</u>	

Junior Year				Senior Year			
Fall Term			Credit	Fall Term			Credit
CHEM	326	Bioanalytical Chemistry.....	4	CHEM	441	Inorganic Chemistry I.....	4
CHEM	330	Biochemistry I....	4	CHEM	401	Chemistry Seminar I.....	1
CHEM	361	****Physical Chemistry I...	4	CHEM	490	Chemistry Research.....	1
HSS		Elective.....	4			##Advanced Chemistry or	
						Biochemistry Elective	4
			<u>16</u>			Advanced Biology Elective .	4
						Free Elective.....	4

Winter Term			Credit				18
CHEM	327	Advanced Analytical	4				
CHEM	362	****Physical Chemistry II...	4	Winter Term			Credit
CHEM	331	Biochemistry II.....	4				
HSS		Elective.....	4	CHEM	402	Chemistry Seminar II	1
				CHEM	490	Chemistry Research.....	1
				HSS		Elective.....	4
			16				

Spring Term				Chemistry, Biochemistry	
			Credit		
				Chemistry, Biochemistry.....	4
				Free Elective.....	4
					<hr/>
CHEM	363	Quantum Chemistry & Molecular Spectroscopy.	4		14
CHEM	430	Advanced Biochemistry	4		
CHEM	433	Biochemistry Lab.....	2	Spring Term	
HSS		Elective.....	4		Credit
CHEM	490#	Research.....	1		
			<hr/>		
			15		
				CHEM 403 Chemistry Seminar III.....	1
				HSS Elective.....	4
				Free Elective.....	4
				Free Elective.....	4
					<hr/>
					13

Total credits required: 192

Notes:

Two degree or double major programs in biochemistry and either chemistry or biochemistry and molecular biology is not allowed.

*Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113. Biochemistry majors may replace CHEM 111, CHEM 113, and CHEM 115 with CHEM 201, CHEM 202, and 4 additional credits of chemistry, which must include a 1 credit laboratory experience. The typical student will be well served by taking CHEM 115.

****Under circumstances EM 104 may be substituted for a biology course.**

***MA 381 also meets this requirement

****CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.

#Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year. Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441	4
Biochemistry	330, 331, 430, 433	14
Research & Literature	291, 490	7
Seminar	401, 402, 403	3
Electives		8
Total		84

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total
Chemistry	76	8	84
Physics	12	0	12
Mathematics	23	0	23
Biology	20	0	20
Humanities and Social Sciences	4	32	36
Electives	0	16	16
College and Life Skills	1	0	1
Total	136	56	192



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Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Biomedical Engineering

Programs - Biomedical Engineering

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (<http://www.bls.gov>), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Program Educational Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- Have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- Be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- Have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

instrumentation.

- Be able to work safely, independently, and confidently in a laboratory environment.
- Be able to design and conduct experiments, making measurements from both living and non-living systems.
- Be able to analyze and present results of experiments, using graphical techniques and statistical analyses.
- Be able to assimilate knowledge from diverse areas to solve problems of importance to the biomedical and engineering sciences.
- Be able to communicate effectively with colleagues and with non-technical audiences, in oral, graphical and written formats.
- Be able to function in multidisciplinary teams in different roles.
- Be aware of how the rapid developments of biomedical engineering necessitate continual updating of skills.
- Have the skills required for self-learning.
- Be able to evaluate the ethical dimensions of issues relevant to biomedical engineering.
- Be aware of the impacts, both positive and negative, that advancements in biomedical engineering have on local and global society.
- Be able to assess client needs, identify relevant constraints (e.g. regulatory, manufacturing, economic, environmental, societal, etc.), and formulate the design problem.
- Be able to generate multiple, creative solutions for a problem and develop criteria by which to rank the merit of feasible solutions.
- Be able to critically review the performance of a solution in achieving the identified needs and suggest relevant improvements or necessary revisions.

BIOMEDICAL ENGINEERING PLAN OF STUDY

Freshman Year

Fall Term		Credit	
AB	110	Cell Structure and Function	4
PH	111	Physics I	4
MA	111	Calculus I	5
CLSK	100	College & Life Skills	1
EM	104	Graphical Communication	2
			16

Winter Term

		Credit	
AB	120	Comparative Anatomy & Physiology	4
PH	112	Physics II	4
MA	112	Calculus II	5
BE	100	Problem Solving in the Biological Sciences and Engineering	4
			17

Spring Term

		Credit	
PH	113	Physics III	4
RH	131	Rhetoric & Composition	4
MA	113	Calculus III	5
EM	121	Statics and Mechanics of Materials I	4
			17

Junior Year

Fall Term		Credit	
BE	310	Physiological Systems I	4
AB	210	Genetics	4
RH	330	Technical and Professional Communication	
		or	
HSS		Elective	4
EM	204	Statics and Mechanics of Materials II	4

Sophomore Year

Fall Term		Credit	
ES	201	Conservation and Accounting Principles	4
CHEM	105	Engineering Chemistry I	4
MA	221	Differential Equations I	4
ES	203	Electrical Systems	4
			16

Winter Term

		Credit	
ES	202	Fluid and Thermal Systems	3
ES	204	Mechanical Systems	3
MA	222	Differential Equations II	4
CHEM	107	Engineering Chemistry II	4
HSS		Elective	4
			18

Spring Term

		Credit	
BE	201	Biomedical Measurements	4
AB	130	Evolution and Diversity	4
ES	205	Analysis & Design of Engineering Systems	4
MA	223	Engineering Statistics I	4
			16

Senior Year

Fall Term		Credit	
BE	410	Biomedical Engineering Design I	4
HSS		Elective	4
		Free Elective	4
BE		Area Elective	4
			16
Winter Term		Credit	

			16	BE	420	Biomedical Engineering Design II	4
Winter Term	Credit			HSS		Elective	4
BE	320	Physiological Systems II	4			Free Elective	4
BE	331	Biomechanics	3	BE		Area Elective	4
BE	351	Biomedical Engineering Lab	2				16
BE	361	Biomaterials	3				
HSS	Elective			Spring Term	Credit		
	or			BE	430	Biomedical Engineering Design III	2
RH	330	Technical and Professional Communication	4	HSS		Elective	4
						Free Elective	4
			16	BE		Area Elective	4
							14
Spring Term	Credit						
SV	304	Bioethics	4				
HSS		Elective	4				
BE	390	Principles of Biomedical Engineering Design	2				
BE		Area	4				
			14				

Total credits required: 192

* 200 level or higher engineering course, or consent of the department head

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the ABBE department head. Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 516	Introduction to MEMS
BE 519	Advanced MEMS
BE 539	Multiscale Biomechanics
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**and	Design for Manufacturing
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both

**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols
BE 516	Introduction to MEMS
BE 435/535	Biomedical Optics

BE 555	Electrophysiology
ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course	Title
ME 317**and	Design for Manufacturing
BE 317**	Design for Biomedical Manufacturing
BE 525	Biomedical Fluid Mechanics
BE 531	Biomechanics II
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopaedic Biomechanics
BE 550	Research Methods in Biomechanics
EM 403	Advanced Mechanics of Materials
ME 422	Finite Elements for Engineering Applications
ME 520	Computer-Aided Design and Manufacturing
ME 522	Advanced Finite Element Analysis

Biomedical Engineering Area Minor

The biomedical engineering area minor is intended to provide a strong biomedical engineering background to undergraduate students who are interested in pursuing careers in the biomedical industry and the health care related fields.

In order to complete the requirements in the biomedical engineering area minor, a student must complete AB110 "Cell Structure and Function" and 16 credits from list shown below. At least three of the courses must have a BE prefix.

Biomedical Engineering Minor	PH	4	Biophysics
Electives		302	

AB 411	4	Genetic Engineering
BE 310	4	Analysis of Physiological Systems I
BE 320	4	Analysis of Physiological Systems II
BE 331	3	Biomechanics
BE 340	4	Biomedical Instrumentation
BE 350	4	Biocontrol Systems
BE 351	2	Biomedical Engineering Lab *
BE 352	1	Biomechanics Lab *
BE 353	1	Biomaterials Lab *

BE 361	3	Biomaterials
BE 435/535	4	Biomedical Optics
BE 482	4	Bioengineering Statistics
BE 510	4	Biomedical Signal and Image Processing
BE 525	4	Biomedical Fluid Mechanics
BE 531	4	Biomechanics II
BE 534	4	Soft Tissue Mechanics
BE 539	4	Multiscale Biomechanics
BE 541	4	Medical Imaging
BE 543	4	Neuroprosthetics
BE 545	4	Orthopaedic Biomechanics
BE 550	4	Research Methods in Biomechanics
BE 555	4	Electrophysiology
BE 560	4	Tissue-Biomaterial Interactions
BE 570	4	Introduction to Tissue Engineering

*Students getting credit for BE351 cannot get credit for BE352 or BE353.

In addition to courses on the above list, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

Basic Engineering Courses

- EM 121 Statics and Mechanics of Materials I
- EM 204 Statics and Mechanics of Materials II
- EM 301 Fluid Mechanics
- ECE 130 Introduction to Logic Design
- ECE 200 Circuits & Systems
- ES 201 Conservation & Accounting Principles
- ES 202 Fluid & Thermal Systems
- ES 203 Electrical Systems
- ES 204 Mechanical Systems
- CHE 201 Conservation Principles and Balances
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in biomedical engineering should consult with the Head of the Department of Applied Biology and Biomedical Engineering.



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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemical Engineering

Programs - Chemical Engineering

As has been done since we awarded the nation’s first degree in chemical engineering in 1889, the undergraduate program in chemical engineering undertakes to prepare individuals for careers in the chemical process industries. These include all industries in which chemical and energy changes are an important part of the manufacturing process, such as the petroleum, rubber, plastics, synthetic fiber, pulp and paper, fermentation, soap and detergents, glass, ceramic, photographic and organic and inorganic chemical industries. In view of the dynamic nature of this technology, the course of study stresses fundamental principles rather than technical details. It prepares the student either for advanced study at the graduate level or for immediate entrance into industry. Opportunities in the process industries are found in a variety of activities, including design, development, management, production, research, technical marketing, technical service, or engineering.

Mission: To provide an excellent chemical engineering education through a combination of theory and practice that prepares students for productive professional careers and advanced graduate studies.

Program Educational Objectives

Program Educational Objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve in three to five years.

- Apply a strong academic foundation to make early career contributions to the profession.
- Work in teams to tackle diverse, open-ended problems and to effectively communicate their findings.
- Apply skills for a long-term, productive career in an ever changing global environment.

Program Outcomes

Program Outcomes are statements that describe what students are expected to know and be able to do by the time of graduation.

1. Apply skills and knowledge to formulate and solve chemical engineering problems.
2. Design and conduct experiments and analyze and interpret the resulting data.
3. Define project specifications and design a process or system to meet those specifications.
4. Work effectively in teams.
5. Communicate effectively in presentations and reports.
6. Make appropriate use of computer-based tools, such as process simulators and numerical analysis packages.
7. Understand the ethical and professional responsibilities of a chemical engineer.
8. Understand how chemical engineering impacts the global society.
9. Be prepared to engage in life-long learning.
10. Understand how the chemical engineering profession is related to contemporary issues.

Curriculum

The curriculum covers a breadth of fundamental principles so that the chemical engineering graduates have a working knowledge of advanced chemistry, material and energy balances applied to chemical processes; thermodynamics; heat, mass, and momentum transfer; chemical reaction engineering; separation operations, process design and control. The program provides students with appropriate modern experimental and

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

computing techniques in unit operation laboratory and requires them to work in teams and submit written and oral reports on their laboratory projects. A capstone experience in senior year gives students an opportunity to integrate their knowledge. Also included is the study of health, safety, environmental and ethical issues in the chemical engineering profession.

Graduate work leading to the degree of Master of Science in chemical engineering provides a more thorough understanding of the discipline and enhances a student's ability to handle complex problems. A thesis is required, but that requirement may be waived in exceptional circumstances. Most recent graduate students have chosen research topics in biotechnology, polymers, or automatic control, but other specialties also are possible.

Area Minor in Chemical Engineering

The area minor in chemical engineering is designed to introduce principles of chemical engineering to students majoring in other disciplines. Participation in this area minor will help students to understand chemical engineering aspects of industrial processes and enter a graduate program in chemical engineering if they desire.

Students who complete the area minor in chemical engineering during their sophomore and junior years open the possibility of taking some chemical engineering electives during their senior years.

The area minor in chemical engineering has the following requirements:

- CHE 201 Conservation Principles and Balances or equivalent
- CHE 202 Basic Chemical Process Calculations
- CHE 301 Fluid Mechanics or equivalent
- CHE 303 Chemical Engineering Thermodynamics or equivalent
- CHE 304 Multi-Component Thermodynamics
- CHE 325 Mass Transfer
- CHE 314 Heat Transfer or equivalent

Completion of a minimum of 12 credit hours of courses with prefix CHE at 300 level or above is required toward the minor. Students interested in the CHE area minor should consult the CHE Department Head and receive approval for equivalent courses to be considered.

Area Minor in Biochemical Engineering

The biochemical engineering minor is designed to allow students to concentrate in an area of study that will give them a solid foundation for further work in the pharmaceutical or biotechnology process industry.

To successfully complete a minor in Biochemical Engineering, a student must take six courses as follows:

Four required courses:

- AB110 - Cell Structure and Function
- CHEM330 - Biochemistry
- CHE545 - Introduction to Biochemical Engineering
- CHE 546 - Bioseparations

And then choose two courses from the following list of electives (the two courses cannot also be used towards another minor or second major):

- AB210 - Mendelian and Molecular Genetics
- AB220 - Prokaryotic Cell and Molecular Biology
- or
- AB230 - Eukaryotic Cell and Molecular Biology
- AB411 - Genetic Engineering
- AB421 - Applied Microbiology
- AB431 - Genomics and Proteomics
- CHEM430 - Advanced Biochemistry
- CHEM433 - Biochemistry Lab (recommended but not required)

Interested students should obtain a form from the Chemical Engineering Department secretary

CHEMICAL ENGINEERING

Approximately one-half of the students will follow schedule A1, and one-half will follow schedule A2. Depending on the students' schedules, elective courses may be taken in terms other than the ones designated.

Freshman Year (A1 Schedule)

Freshman Year (A2 Schedule)

Fall Term			Fall Term		
		Credit			Credit
CHEM 111	General Chemistry I*	4	CHEM 111	General Chemistry I	4
CLSK 100	College & Life Skills	1	CLSK 100	College & Life Skill	1
EM 104	Graphical Communications	2	EM 104	Graphical Communications	2
RH 131	Rhetoric & Composition	4	RH 131	Rhetoric and Composition	4
MA 111	Calculus I	5	MA 111	Calculus I	5
		<hr/> 16			<hr/> 16

Winter Term			Winter Term		
		Credit			Credit
CHEM 113	General Chemistry II*	4	CHEM 113	General Chemistry II	4
PH 111	Physics I	4	PH 111	Physics I	4
HSS	Elective	4	HSS	Elective	4
MA 112	Calculus II	5	MA 112	Calculus II	5
		<hr/> 17			<hr/> 17

Spring Term			Spring Term		
		Credit			Credit
CHE 110	Programming & Computation for Chemical Engineers	2	CHE 110	Programming & Computation for Chemical Engineers	2
CHEM 115	General Chemistry III	4	CHEM 115	General Chemistry III*	4
EM 103	Introduction to Design	2	EM 103	Introduction to Design	2
MA 113	Calculus III	5	MA 113	Calculus III	5
PH 112	Physics II	4	PH 112	Physics II	4
		<hr/> 17			<hr/> 17

Summer Intern/Co-op Sophomore Year (A1 Schedule) Fall Term			Summer Intern/Co-op Sophomore Year (A2 Schedule) Fall Term		
		Credit			Credit
CHE 200	Career Preparation I	0	CHE 200	Career Preparation I	0
CHE 201	Conservation Principles and Balances	4	CHE 201	Conservation Principles and Balances	4
CHEM 251	Organic Chemistry I	4	CHEM 251	Organic Chemistry I	4
MA 221	Differential Equations I	4	MA 221	Differential Equations I	4
HSS	Elective	4	HSS	Elective	4
		<hr/> 16			<hr/> 16

Winter Term			Winter Term		
		Credit			Credit
CHE 202	Basic Chemical Process Calculations	4	CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	4	CHEM 252	Organic Chemistry II	4
MA 222	Differential Equations II	4	MA 222	Differential Equations II	4
EM 101	Statics I	2	EM 101	Statics I	2
		<hr/> 14			<hr/> 14

Spring Term			Spring Term		
		Credit			Credit
CHE 301	Fluid Mechanics	4	MA 223	Engineering Statistics I	4

CHE	303	Chemical Engineering		CHEM	225	Analytical Chemistry I	4
		Thermodynamics	4	HSS		Elective	4
		Elective (Approved)	4	CHE	315	Materials Science	4
HSS		Elective	4				<hr/>
			16				16

Summer Intern/Co-op
Junior Year (A1 Schedule)

Fall Term			Credit
CHE	300	Career Preparation II	0
CHE	304	Multi-Component	
		Thermodynamics	4
CHE	314	Heat	4
		Transfer.....	
CHE	315	Materials Science	4
		
CHEM225		Analytical Chemistry I.....	4
			<hr/>
			16

Winter Term			Credit
CHE	325	Mass Transfer	4
CHEM360		Intro Physical Chemistry	4
MA	223	Engineering Statistics I	4
RH	330	Technical and	4
		Professional	
		Communication	
			<hr/>
			16

Spring Term			Credit
CHE	404	Kinetics & Reactor Design	4
CHE	411	Chemical Engineering Lab	3
		I..	
ECE	206	Elements of Electrical	
		Engineering	4
HSS		Elective	4
			<hr/>
			15

Summer Intern/Co-op

Senior Year (A1 Schedule)

Fall Term			Credit
CHE	409	Professional Practice	1
CHE	412	Chemical Engineering	4
		Lab II	
CHE	416	Design I	4
		Elective (Free)	4
		Elective (CHE)	4
			<hr/>
			17

Winter Term			Credit
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Summer Intern/Co-op

Junior Year (A2 Schedule)

Fall Term			Credit
CHE	300	Career Preparation II	0
CHE	301	Fluid Mechanics	4
CHE	303	Chemical Engineering	
		Thermodynamics	4
		Elective (approved)	4
RH	330	Technical and	4
		Professional	
		Communication	
			<hr/>
			16

Winter Term			Credit
CHE	304	Multi-Component	
		Thermodynamics.....	4
CHE	314	Heat	4
		Transfer.....	
ECE	206	Elements of Electrical	
		Engineering	4
HSS		Elective	4
			<hr/>
			16

Spring Term			Credit
CHE	325	Mass Transfer	4
CHE	411	Chemical Engineering	3
		Lab I.	
CHEM 360		Intro Physical Chemistry	4
HSS		Elective	4
			<hr/>
			15

Summer Intern/Co-op
Senior Year (A2 Schedule)

Fall Term			Credit
CHE	404	Kinetics & Reactor	4
		Design	
CHE	409	Professional Practice	1
CHE	412	Chemical Engineering	4
		Lab II	
CHE	416	Design I	4
		Elective (Free)	4
			<hr/>
			17

Winter Term

				Credit	
CHE	413	Chemical Eng. Lab III	4		
CHE	417	Design II	4	CHE	413 Chemical Eng. Lab III 4
CHE	440	Process Control	4	CHE	417 Design II 4
HSS		Elective	4	CHE	440 Process Control 4
			<hr/>	HSS	Elective 4
			16	<hr/>	
				16	

Spring Term			Credit	Spring Term		Credit
CHE	418	Design III	2	CHE	418 Design III	2
HSS		Elective	4	HSS	Elective	4
HSS		Elective	4		Elective (CHE)	4
		Elective (Approved)	4		Elective (CHE)	4
		Elective (CHE)	4		Elective (Approved)	4
			<hr/>			<hr/>
			18			18

Total credits required: 194

Total credits required: 194

*Rose students who have changed their major to chemical engineering or students who have transferred to Rose and have credit for CHEM 105 and CHEM 107 (formerly CHEM 201 and CHEM 202) do not need to take CHEM 111 and CHEM 113, but must take CHEM 115.

Electives

Chemical Engineering students must complete 28 credits of electives in humanities and social sciences in addition to RH 131 and RH 330. They are also required to take 20 credits of electives (8 credits of CHE electives, 8 credits of approved electives and 4 credits of free electives) in addition to the humanities and social sciences mentioned above. The courses listed below qualify as a CHE elective. In very specific circumstances, independent projects or other courses may qualify as a CHE elective if approved by the department.

- CHE 310 Numerical Methods for Chemical Engineers
- CHE 419 Advanced MEMS: Modeling and Packaging
- CHE 441 Polymer Engineering
- CHE 450 Air Pollution Control
- CHE 461 Unit Operations in Environmental Engineering
- CHE 470 Safety, Health, and Loss Prevention
- CHE 502 Transport Phenomena
- CHE 504 Advanced Reactor Design
- CHE 512 Petrochemical Processes
- CHE 513 Advanced Thermodynamics
- CHE 540 Advanced Process Control
- CHE 545 Introduction to Biochemical Engineering
- CHE 546 Bioseparations

A minimum of eight credits, designated as approved electives, must be approved by the student's academic advisor. Approved electives can be chosen from economics, engineering, engineering management, mathematics, or science courses. Students are encouraged to use their electives to focus their studies in an area of concentration. Some areas of concentration are Engineering Analysis (for students who would like to pursue a graduate degree), Chemistry and Life Sciences, Biotechnology, Material Science, Mathematical Modeling and Simulation, Computer Applications, Semiconductor Materials and Devices, and Environmental Management.

The chemical engineering profession is rapidly changing and knowledge of specialty areas has become essential in the real world. Technical elective courses are intended to provide an opportunity to introduce students to a specialty area in science and engineering and help them to expand their knowledge and expertise in new areas of chemical engineering. Although a minimum of eight credit hours are recommended in an area of concentration, students are encouraged to take all the 20 credit hours of electives in an area of concentration. In many cases students can use their electives to take a package of courses toward an area minor such as, biochemical engineering, applied biology, biomedical engineering, chemistry, environmental engineering or toward a certificate in semiconductor materials and devices.

Undergraduate students have the opportunity to work on a research project under the guidance of one of the departmental faculty members. Students who are interested in learning about research should talk to members of the faculty to define a project of mutual interest and then enroll in CHE499, Directed Research. Credit hours of CHE499 can count toward a technical elective.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Chemistry

Graduates with a degree in chemistry will be well prepared for employment, graduate study in a chemistry-related field, or professional school. Chemists are employed in research, quality control, design, sales and management. Many graduates pursue masters and doctoral degrees in chemistry, biochemistry, medicinal chemistry, materials science, or environmental science, among others. A chemistry degree is excellent preparation for medical school and related fields, and also for careers in business, law or education.

The curriculum at Rose-Hulman Institute of Technology provides a rigorous introduction to all subdisciplines of chemistry. Students have access to modern instrumentation, a new biochemistry lab, and a new environmental chemistry lab. Rose-Hulman students are introduced to modern computational methods beginning in the sophomore year. There are many opportunities for research or other individual projects, and students are encouraged to present their results at regional and national chemistry conferences. Close interaction with engineering departments provides students with a point of view not available at most other undergraduate institutions.

Students may broaden their education by choosing a minor or second major. Many students, including chemistry majors, may be interested in a second major or minor in biochemistry and molecular biology. Other common choices include applied biology, chemical engineering and mathematics.

Chemistry Plan of Study

Freshman Year			Sophomore Year		
Fall Term			Fall Term		
		Credit			Credit
CHEM 111*	General Chemistry I	4	CHEM 251	Organic Chemistry I	4
MA 111	Calculus I	5	MA 221	Differential Equations &	
AB 101				Matrix Algebra I	4
	or		PH 113	Physics III	4
AB 110**	Biology	4		Free Elective	4
CLSK 100	College and Life Skills	1			
RH 131	Rhetoric and				16
	Composition				
	or				
HSS	Elective	4			
		18			
Winter Term			Winter Term		
		Credit			Credit
CHEM 113*	General Chemistry II	4	CHEM 252	Organic Chemistry II	4
MA 112	Calculus II	5	CHEM 291	Intro to Undergraduate	4
PH 111	Physics I	4		Research	
RH 131	Rhetoric and		MA 223* **	Engineering Statistics I	4
	Composition			Free Elective	4
					16
Spring Term			Spring Term		
		Credit			Credit

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

or					
HSS	Elective	4	CHEM 253	Organic Chemistry III	4
			CHEM 225	Analytical Chemistry I	4
		<hr/> 17	HSS	Elective	4
			PH 113	Free Elective	4
Spring Term					<hr/> 16
	Credit				
CHEM 115	General Chemistry III	4			
MA 113	Calculus III	5			
HSS	Elective	4			
PH 112	Physics II	4			
		<hr/> 17			
Junior Year			Senior Year		
Fall Term			Fall Term		
	Credit			Credit	
CHEM 326	Bioanalytical Chemistry	4	CHEM 441	Inorganic Chemistry I	4
CHEM 361	****Physical Chemistry I	4	CHEM 401	Chemistry Seminar I	1
CHEM 330	Biochemistry I	4	CHEM 490	Research	1
HSS	Elective	4		Chemistry Elective	4
				Free Elective	4
		<hr/> 16			<hr/> 14
Winter Term			Winter Term		
	Credit			Credit	
CHEM 327	Advanced Analytical	4	CHEM 442	Inorganic Chemistry II	4
CHEM 362	****Physical Chemistry II	4	CHEM 402	Chemistry Seminar II	1
HSS	Elective	4	CHEM 490	Research	1
	Free Elective	4	HSS	Elective	4
		<hr/> 16		Chemistry Elective (400-	4
				level)##.	
				Free Elective	4
Spring Term					<hr/> 18
	Credit				
CHEM 363	Quantum Chemistry & Molecular Spectroscopy.	4	Spring Term		
				Credit	
CHEM 451	Organic Structure Determination	4	CHEM 403	Chemistry Seminar III	1
HSS	Elective	4	HSS	Elective	4
	Free Elective	4		Free Elective	4
CHEM 490#	Research	1		Free Elective	4
		<hr/> 17			<hr/> 13

Total credits required: 194

Notes:

- Two degree or double major programs in chemistry and biochemistry is not allowed.
- *Subject to approval, CHEM 112 may be substituted for CHEM 111 and CHEM 113. Chemistry majors may replace CHEM 111 and CHEM 113 with CHEM 105 and CHEM 107. These courses must be taken in these combinations. That is, CHEM 111 and CHEM 113, or CHEM 105 and CHEM 107.
- **Under circumstances EM 104 may be substituted for a biology course.
- ***MA 381 also meets this requirement
- ****CHE 303, CHE 304 and CHEM 360 may be substituted for CHEM 361 and CHEM 362.
- #Students must complete at least 3 credits of CHEM 490 prior to the Spring quarter of their senior year.

Students may count up to 8 credits of research toward their electives, of which no more than 2 credits can come from CHEM 290.

- ##Research and independent study do not meet this requirement.

List of Required Chemistry Courses

Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441, 442	10
Biochemistry	330	4
Organic Structure Determination	451	4
Seminar	401, 402, 403	3
Research & Literature	291, 490	3
Electives		8
Total		80

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total
Chemistry	72	8	80
Physics	12	0	12
Mathematics	23	0	23
Biology	4	0	4
Humanities and Social Sciences	4	32	36
Electives	0	36	36
College and Life Skills	1	0	1
Total	116	76	192

Area Minor in Chemistry

Students not taking a first or second major in chemistry may earn an Area Minor in Chemistry by successfully completing the sequence of courses listed below. The student desiring this minor must request the approval of the Department Head and file the appropriate form with the registrar. This form is available on the Department of Chemistry webpage.

The requirements for an area minor in chemistry for students with a first or second major in applied biology or chemical engineering are different from those majoring in other disciplines.

Area Minor in Chemistry for Most Students

Course Number	Course Title	Credits
CHEM113	General Chemistry II	4
CHEM115	General Chemistry III	4
CHEM225	Analytical Chemistry	4
CHEM251	Organic Chemistry I	4
CHEM252	Organic Chemistry II	4
CHEMXXX	300 or 400 Level Chemistry Elective	4
Total		24

Area Minor in Chemistry for Chemical Engineering and Applied Biology Majors

Course Number	Course Title	Credits
---------------	--------------	---------

CHEM253	Organic Chemistry III	4
CHEM225	Analytical Chemistry	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student’s major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.



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About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Civil Engineering

Civil engineering is a people-oriented profession that has long been in existence to serve the needs of mankind. It evolved as a formal discipline at the start of the 19th century with the advent of society's need for increased mobility and convenience. The role of the civil engineer has always been one that deals primarily with public works: the planning, design, and construction of airports, bridges, buildings, and transportation, irrigation, flood control, water supply and waste disposal systems. These civil engineering works not only manage our environment, but are part of the environment itself and, by their very nature, have important social and economic impacts.

The civil engineering curriculum is designed to give the student a sound education in preparation for this role. The first two years include courses that deal with the principles of mathematics, physical and engineering sciences on which engineering concepts are based, as well as courses in humanities and social sciences and introductory courses in engineering and design. The last two years are devoted to developing the necessary technical competence, as well as the ability to apply the knowledge that the student has acquired to the design and synthesis of complex civil engineering projects. Project-based learning is an essential ingredient, and a year-long, client-based capstone design project highlights the senior year.

The entire curriculum is oriented to develop a student's ability to think critically and logically. Upon graduation the student will be able to adapt this ability to the engineering environment of his or her choice. The curriculum in civil engineering will provide the student with the capacity for professional growth, either by advanced study or as a practicing professional engineer. A student may also use this academic background as a stepping stone to a position in management, administration, law, or some other non-engineering field.

Civil Engineering Department's Mission Statement

To provide an excellent civil engineering education that prepares graduates to develop into professionals who will exceed the needs of their employers, clients, and community in a continually changing world.

Civil Engineering Department's Program

Educational Objectives and Student Learning Outcomes*

Graduates will demonstrate the ability to **perform essential engineering functions** in the design, management, or construction industry. Supporting learning outcomes are as follows:

- **Technical Core** – Solve problems in mathematics (through differential equations), probability and statistics, calculus-based physics, chemistry, and an additional area of science.
- **Experiments** – Design an experiment or experimental program to meet a need; conduct civil engineering experiments, and analyze and interpret the resulting data.
- **Engineering Problems** – Develop problem statements and solve well-defined engineering problems in four technical areas appropriate to civil engineering.
- **Engineering Impact** – Explain the impact of engineering solutions on the economy, environment, political landscape, and society; apply the principles of sustainability to the design of engineering systems.
- **Contemporary Issues** – Explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Graduates will demonstrate the ability to **design/construct complex engineering systems** in the broad-based engineering industry. Supporting learning outcomes are as follows:

- **Design** – Design a system or process in more than one civil engineering context to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.
- **Multidisciplinary** – Function effectively as a member of a multidisciplinary team.
- **Professional/Ethical** –Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action and explain the importance of professional licensure.
- **Communication** – Organize and deliver effective verbal, written, and graphical communications.
- **Engineering Tools** – Apply relevant techniques, skills, and modern engineering tools to solve engineering problems.

Graduates will demonstrate their **potential for technical leadership and management**. Supporting learning outcomes are as follows:

- **Life Long Learning** – Explain the need for and demonstrate the ability to learn on their own, without the aid of formal instruction.
- **Leadership** – Apply leadership principles to direct the efforts of a small group.
- **Service** – Use one's time and skills to benefit an individual or community without cost to the recipient.
- **Project Management** – Explain key concepts in project management, and develop solutions to well-defined project management problems.
- **Business and Public Administration** – Explain key concepts and processes used in business, public policy, and public administration.
- **Cultural and Global Awareness** – Analyze and interpret cultural perspectives and social systems that define human characteristics.

** The civil engineering program uses the term “educational objective” to describe the expected accomplishments of our students in three to five years following graduation. The term “student learning outcome” is used to describe knowledge and skills at the time of graduation.*

Civil Engineering Plan of Study

Freshman Year

<i>Fall Term</i>		<i>Credit</i>
MA	111 Calculus I	5
PH	111 Physics I	4
RH	131 Rhetoric and Composition or Elective (HSS)	4
EM	104 Graphical Communications.	2
CLSK	100 College and Life Skills	1
		16

<i>Winter Term</i>		<i>Credit</i>
MA	112 Calculus II	5
PH	112 Physics II	4
	Elective (HSS) or	
RH	131 Rhetoric and Composition	4
CE	110 Computer Applications and GIS	4
		17

<i>Spring Term</i>		<i>Credit</i>
--------------------	--	---------------

Sophomore Year

<i>Fall Term</i>		<i>Credit</i>
MA	221 Differential Equations and Matrix Algebra I	4
CHEM	105 Engineering Chemistry I	4
EM	202 Dynamics	4
	Elective (HSS)	4
CE	201 Engineering Surveying II	2
		18

<i>Winter Term</i>		<i>Credit</i>
MA	222 Differential Equations and Matrix Algebra II	4
EM	203 Mechanics of Materials	4
	Elective (HSS)	4
CHEM	107 Engineering Chemistry II	4
		16

<i>Spring Term</i>		<i>Credit</i>
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MA	223 Statistics for	4
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<i>Fall Term</i>	<i>Credit</i>
------------------	---------------

CE	321 Structural Mechanics I	4
CE	336 Soil Mechanics	4
ECE	206 Elements of Electrical Eng or	
CHE	201 Conservation Principles and	4
CE	371 Hydraulic Engineering	4
		16

Credit

ME	201 Thermodynamics or	
CHE	202 Basic Chemical Process Calculations	4
CE	441 Construction Engineering	2
CE	432 Concrete Design I	3
CE	471 Water Resources Engineering Elective (Science)	4
		17

Credit

CE	310 Civil Engineering	2
	Numerical Methods	
CE	431 Steel Design I	3
CE	460 Environmental	4
	Engineering	
RH	330 Technical and	4
	Professional	
	Communication	
CE	461 Environmental	2
	Engineering Lab	
		15

<i>Fall Term</i>	<i>Credit</i>
------------------	---------------

CE	489 C.E. Design & Synthesis	2
	*Elective (Technical)	4
CE	450 C.E. Codes & Regulations	4
	Elective (HSS)	4
	Elective (HSS)	4
		18

Credit

CE	489 C.E. Design & Synthesis	4
CE	**C.E. Elective	4
	*Elective (Technical)	4
CE	303 Engineering Economy	4
		16

Credit

CE	489	C.E. Design & Synthesis	2
		*Elective (Technical)	4
		Elective (HSS)	4
		Elective (HSS)	4
CE	400	Career Preparation Seminar	0
			14

**Total credits
required: 194**

Environmental Engineering Area Minor

<https://www.rose-hulman.edu/course-catalog/course-catalog-2009-2010/programs-of-study/civil-engineering.aspx> [1/20/2017 1:19:01 PM]

student to tailor the minor to their academic majors and special interests.

The 3 required courses are as follows:


CHEM 264	Introduction to Environmental Science
CE 460	Introduction to Environmental Engineering
CE 471	Water Resources Engineering

And 3 electives from the following list:

- CE 561/CHE 450 Air Pollution Control
- CE 562 Treatability Studies
- CE 563/CHE 461 Unit Operations in Environmental Engineering
- CE 564 Environmental Chemistry
- CE 565 Solid and Hazardous Waste Regulation and Treatment
- CE 566 Environmental Management
- CE 567 Applied Hydrologic Modeling
- CE 568 Applied Contaminant Transport Modeling
- CE 569 Environmental Systems Optimization
- CE 573 Groundwater Analysis
- CE 590 Special Problems
- CHE 470 Safety, Health, and Loss Prevention
- VA 452 Environmental Economics
- ME 331 Energy-Material Resource Recovery and Utilization
- ME 513 Environmental Noise
- AB 320 Ecology and Environmental Biology

Advisor:

Dr. Michael A. Robinson,
Department of Civil Engineering
Olin 225D, 812/877-8286
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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Engineering

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

Computer Engineering Student Learning Outcomes

The mission statement for the ECE (Electrical & Computer Engineering) Department: To provide students in ECE a rigorous learning experience that prepares them for professional careers.

CPE Student Learning Outcomes: CPE student learning outcomes are designed to instill in our graduates the skills appropriate to their professions and life-long learning. The CPE program uses the term “**student learning outcomes**” to describe knowledge and skills at the time of graduation that are derived from the objectives.

Holistic Education: Computer Engineering graduates shall be prepared to practice the profession of engineering using a systems perspective broad enough to encompass technological, economic, ethical, environmental, social, and human issues, shall have demonstrated a facility for independent learning, and shall be prepared for continued professional development.

- H1: Demonstrate a facility for independent learning
- H2: Be prepared for continued professional development
- H3: Effective communications skills
- H4: Contemporary Issues
- H5: Role of professional in global society

Technical Preparation: Electrical and Computer Engineering graduates shall demonstrate technical depth and breadth in their discipline.

- T1: General engineering science core plus a discipline-specific technical core
- T2: Effective use of contemporary tools of the engineering profession

Design & Professional Practice: Computer Engineering graduates shall have participated in design experiences including a comprehensive, industrially-oriented design project, oral presentations, and written communications.

- D&P: Client sponsored team design experience

Computer Engineering Plan of Study

Freshman Year

Fall Term		Credit	
PH	111 Physics I	4	
MA	111 Calculus I	5	
CLSK	100 College and Life Skills	1	

Sophomore Year

Fall Term		Credit	
MA	221 Differential Equations & Matrix Algebra I	4	
CSSE	232 Computer Architecture I	4	

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

RH	131	Rhetoric & Composition		ECE	203	DC Circuits	4
		or		CHEM	105	Engineering Chemistry I	4
HSS		Elective	4				16
ECE	160	Engineering Practice	2				
			16				
				<i>Winter Term</i>			
							<i>Credit</i>
<i>Winter Term</i>			<i>Credit</i>	MA	222	Differential Equations & Matrix Algebra II	4
PH	112	Physics II	4	CSSE	332	Operating Systems	4
MA	112	Calculus II	5				
CSSE	120	Introduction to Software Development	4	ECE	204	AC Circuits	4
HSS		Elective		HSS		Elective	4
		or					16
RH	131	Rhetoric & Composition.....	4				
			17	<i>Spring Term</i>			
							<i>Credit</i>
<i>Spring Term</i>			<i>Credit</i>	MA	381	Introduction to Probability with Applications to Statistics	4
PH	113	Physics III	4	ECE	250	Electronic Device Modeling	4
MA	113	Calculus III	5	ECE	205	Dynamical Systems	4
ECE	130	Introduction to Logic Design	4	HSS		Elective	4
CSSE	220	Object-Oriented Software Development	4				16
			17				
Junior Year				Senior Year			
<i>Fall Term</i>				<i>Fall Term</i>			
			<i>Credit</i>				<i>Credit</i>
MA	275	Discrete & Combinational Algebra I	4	ECE	460	Engineering Design I	3
ECE	351	Analog Electronics	4			Tech Elective	4
ECE	333	Digital Systems	4			Area Elective	4
RH	330	Technical and Professional Communication	4	HSS		Elective	4
			16				15
				<i>Winter Term</i>			
							<i>Credit</i>
<i>Winter Term</i>			<i>Credit</i>	ECE	461	Engineering Design II	4
ECE	300	Signals & Systems	4			Tech Elective	4
ECE	331	Embedded System Design	4			Area Elective	4
ECE	332	Computer Architecture II	4	HSS		Elective	4
		Math/Science Elective	4				16
			16				
				<i>Spring Term</i>			
							<i>Credit</i>
<i>Spring Term</i>			<i>Credit</i>	ECE	462	Engineering Design III	2
ECE	380	Discrete Time & Continuous Systems	4			Area Elective	4
ECE	342	Introduction to Electromagnetic Compatibility	4	HSS		Elective	4
						Free Elective	4
ECE	362	Principles of Design	3			Free Elective	4
HSS			4				18
			15				
				Total credits required: 194			

Area Electives

An area elective course is:

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Elective

- Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

Notes

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. CPE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other Rose-Hulman courses.
- 3. CPE majors may take any additional math, biology, chemistry, or physics course as a science elective except those courses that are cross-referenced with any engineering courses.

Computer Engineering Core Courses

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE160	Engineering Practice	2
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE250	Electronic Device Modeling	4
ECE300	Signals & Systems	4
ECE331	Embedded System Design	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4
ECE342	Introduction to Electromagnetic Compatibility	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE380	Discrete Time & Continuous Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

Second Major in Computer Engineering

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in CPE by completing all of the courses in a required plan.

CPE Second Major

Course Number	Course Name	Credit
ECE 130	Introduction to Logic Design	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 250	Electronic Device Modeling	4
ECE 300	Signals & Systems	4
ECE 331	Embedded System Design	4
ECE 332	Computer Architecture II	4
ECE 333	Digital Systems	4
ECE 342	Introduction to Electromagnetic Compatibility	4

ECE 351	Analog Electronics	4
ECE 380	Discrete Time & Continuous Systems	4
CSSE 120	Introduction to Software Development	4
CSSE 220	Object-Oriented Software Development	4
CSSE 232	Computer Architecture I	4
CSSE 332	Operating Systems	4
Total		64

Area Minor in Electrical and Computer Engineering (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Fred Berry

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE205	Dynamical Systems	4
ECE300	Signals and Systems	4
ECE380	Discrete Time and Continuous Systems	4
ECE310	Communication Systems	4

Example Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits
ECE130	Introduction to logic Design	4
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is

more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless System
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science

The Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The computer science curriculum is designed to prepare students for multiple careers in a rapidly changing environment. The department's courses emphasize fundamental concepts and techniques that will last longer than present technology.

Computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer architecture, programming languages, operating systems, and software engineering. Majors also complete important courses in closely related fields, e.g., discrete mathematics, digital logic design, and probability and statistics. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Courses in database systems, compilers, computer graphics, fractals and chaotic dynamical systems, artificial intelligence, theory of computation, analysis of algorithms, computer networks, computer vision, web-based information systems, and cryptography are available as advanced electives. A three-term senior project provides valuable practical experience in the specification, design, implementation, and documentation of large software systems. Qualified students can undertake independent study in advanced topics in computer science, participate in a research project with a faculty member, or complete a senior thesis.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

Computer science majors have diverse interests and career goals. Five free elective courses allow students to tailor their undergraduate education to their specific goals. Students planning to undertake graduate study in computer science usually take additional advanced courses in computer science, electrical engineering, and mathematics.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Computer science majors have unlimited access to the department's laboratories. Computer science majors are frequently employed by the computing center as user consultants, and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities throughout the year and sponsors the school's programming teams which compete in local, regional, and national contests. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Computer Science Program Educational Objectives

Graduates from the computer science program will be prepared for many types of careers in the computing industry and be prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

Computer Science Program Outcomes

By the time students graduate with a computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools
2. Anticipate complexities and problems involved in the development of large software systems
3. Analyze requirements, design software that satisfies those requirements, and implement that software
4. Analyze problems using ideas of problem complexity, models of computation, and decidability
5. Design algorithms using a variety of paradigms
6. Analyze algorithms in terms of correctness, as well as time and space efficiency
7. Communicate effectively, both verbally and in writing
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
10. Collaborate effectively in small teams
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
12. Explain the impact of globalization on computing and software engineering

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

There are many alternatives to the schedule below. Students with special interests or opportunities (e.g., advanced placement) should determine what schedule is best for their own plan of study by examining schedules at the department's web site: www.cs.rose-hulman.edu.

Freshman Year

<i>Fall Term</i>				<i>Credit</i>
CSSE	120	Introduction to Software Development	4	
MA	111	Calculus I	5	
PH	111	Physics I	4	
RH	131	Rhetoric & Composition	4	
CLSK	100	College and Life Skills	1	
				18

<i>Winter Term</i>				<i>Credit</i>
CSSE	220	Object-Oriented Software Development	4	
MA	112	Calculus II	5	
PH	112	Physics II	4	
HSS		Elective	4	

Sophomore Year

<i>Fall Term</i>				<i>Credit</i>
CHEM	105	Engineering Chemistry I	4	
CSSE	232	Computer Architecture I	4	
MA	221	Differential Equations and Matrix Algebra I	4	
MA	275	Discrete & Combinatorial Algebra I	4	
				16

<i>Winter Term</i>				<i>Credit</i>
CSSE	230	Data Structures and Algorithm Analysis	4	
CSSE	333	Database Systems	4	
MA	375	Discrete & Combinatorial Algebra II	4	

	17		HSS	Elective	4
					16
<i>Spring Term</i>					
		<i>Credit</i>		<i>Spring Term</i>	<i>Credit</i>
ECE	130	Introduction to Logic Design		4	
MA	113	Calculus III		5	
HSS		Elective		4	
Science		Elective		4	
				17	
Junior Year					
<i>Fall Term</i>					
		<i>Credit</i>			
CSSE	371	Software Requirements & Specification		4	
CSSE/MA	473	Design and Analysis of Algorithms		4	
CSSE		Elective		4	
HSS		Elective		4	
				16	
<i>Winter Term</i>					
		<i>Credit</i>			
CSSE	332	Operating Systems		4	
CSSE	374	Software Architecture and Design		4	
CSSE/MA	474	Theory of Computation		4	
HSS		Elective		4	
				16	
<i>Spring Term</i>					
		<i>Credit</i>			
CSSE		Elective		4	
ECE/MA		Elective		4	
Free		Elective		4	
Free		Elective		4	
				16	

CSSE electives cannot include any of CSSE 372, 373, and 375 through 377. Science elective is any CHEM, PH, or AB courses totaling at least 4 credits.

<i>Spring Term</i>					
CSSE	304	Programming Lang. Con		4	
ECE	332	Computer Architecture II		4	
MA	381	Introduction to Probability with Statistical Applications		4	
RH	330	Technical and Professional Communication		4	
				16	
Senior Year					
<i>Fall Term</i>					
CSSE	487	Senior Research Project I			
		or			
CSSE	497	Senior Project I			
		or			
CSSE	494	Senior Thesis I		4	
CSSE		Elective		4	
HSS		Elective		4	
Free		Elective		4	
				16	
<i>Winter Term</i>					
CSSE	488	Senior Research Project II			
		or			
CSSE	498	Senior Project II			
		or			
CSSE	495	Senior Thesis II		4	
CSSE		Elective		4	
HSS		Elective		4	
ECE/MA		Elective		4	
				16	
<i>Spring Term</i>					
CSSE	489	Senior Research Project III			
		or			
CSSE	499	Senior Project III			
		or			
CSSE	496	Senior Thesis III		4	
Free		Elective		4	
Free		Elective		4	
				12	

Total credits required: 192

ECE/MA electives must be approved by the CSSE department head.
HSS electives must be distributed as

required by HSS.

Summary of graduation requirements for the computer science major

To complete the major in computer science a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE374, CSSE473 or MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA275, MA221, MA375, MA381; ECE130, ECE332; PH111, PH112; CHEM105; RH131, RH330; CLSK100.
2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 377. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
3. Eight credits of technical elective courses selected from the courses offered by the Department of Mathematics or the Department of Electrical and Computer Engineering. Courses used as technical electives must have been approved for such use by the computer science department head. A student pursuing a second major, minor, or certificate program in an area not offered by the Department of Mathematics or the Department of Electrical and Computer Engineering may substitute one or more technical electives counted towards the second major, minor, or certificate program for MA/ECE electives. These substitutions require approval of the computer science and software engineering department head.
4. Four credits of science electives, which can be any CHEM, PH, or AB courses not already required for the computer science major.
5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course except Military Science and Aerospace Studies.
7. A total of 192 credits.

Area Minor in Computer Science

Advisor: Dr. Laxer

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

- CSSE120 Introduction to Software Development
- CSSE220 Object-Oriented Software Development
- CSSE230 Data Structures and Algorithm Analysis

Four additional courses in computer science numbered above 200. None of these may be CSSE 371-377.



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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Economics

The degree program in Economics is offered by the Department of Humanities and Social Sciences.

The curriculum in Economics is designed to respond to a growing demand for students of economics who are rigorously trained in mathematical methods of analysis. The Rose-Hulman program gives students a broad background in economic analysis and an ability to use sophisticated analytical techniques in their thinking and decision-making. The quantitative training prepares the graduate for further graduate study or for economic analysis work in government or industry.

Students may also obtain a degree with a double major in Economics and another field: mathematics, computer science, etc.

Learning Outcomes:

Upon graduating, Rose-Hulman Economics majors will be able to:

1. explain core economic terms, concepts and theories

2. use economic theory to define, analyze and solve a wide range of problems.

3. collect, process, and interpret data using econometric techniques and statistical inference, especially to test hypotheses and support recommended actions.

4. communicate complex economics topics in both oral and written form.

5. independently undertake in-depth economic analysis.

ECONOMICS PLAN OF STUDY

Freshman Year

Fall Term	Credit
MA 111 Calculus I	5
RH 131 Rhetoric & Composition	or
	*Elective (HSS)
CHEM 111 General Chemistry I	4
CLSK 100 College and Life Skills	4
EM 104 Graphical Communications	1
	2
	16

Winter Term	Credit
CSSE 120 Introduction to Software Development..	4
MA 112 Calculus II	5
PH 111 Physics I	4
	*Elective (HSS)

Sophomore Year

Fall Term	Credit
MA 221 Differential Equations and Matrix Algebra I	4
SV 151 Principles of Economics	4
	*Elective (HSS)
	Elective
	(Physical or Life Science)
	4
	16
Winter Term	Credit
MA 222 Differential Equations and Matrix Algebra II	4
	Elective (Economics)
	*Elective (HSS)
	Elective
	(Physical or Life Science)
	4

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs


		or			
RH	131	Rhetoric & Composition			16
			4		
			17	Spring Term	Credit
				Elective (Math)	4
				Elective (Economics)	4
				*Elective (HSS)	4
				Elective	
				(Physical or Life Science)	4
Spring Term	Credit				
CHEM	113	General Chemistry II			
		or			
AB	101	Essential Biology			
MA	113	Calculus III	4		
PH	112	Physics II	5		16
		*Elective (HSS)	4		
			4		
			17		

*Humanities and Social Science courses are denoted by the prefixes GS, IA, RH, SV, GE, JP, and SP.

In order to permit tailoring each student's program to best suit that student's needs and interests, no specific courses other than in Economics are required in the junior or senior years. However, each student's program must satisfy the following minimum requirements:

- 20 credits of required Economics courses:
SV151 Principles of Economics
IA350 Intermediate Microeconomics
IA351 Intermediate Macroeconomics
SV450 Introduction to Econometrics
XX456 Seminar for Economics Majors
XX457 Directed Study for Economics Senior Project
- 24 additional credits in Economics electives.
- 27 credits in required Mathematics courses:
MA111, 112, 113 Calculus I, II, III
MA221, 222 Differential Equations and Matrix Algebra I, II
MA223 Engineering Statistics I or
MA381 Introduction to Probability
- 12 additional credits in Mathematics other than MA351-356.
- 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
- 24 credits in Physical or Life Science.

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Computer Science	4
Physical or Life Science	24
Free Electives	40
Other	3
TOTAL	190

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Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Electrical Engineering

Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

Electrical Engineering Student Learning Outcomes

The mission statement for the ECE (Electrical & Computer Engineering) Department: To provide students in ECE a rigorous learning experience that prepares them for professional careers.

EE Student Learning Outcomes: EE student learning outcomes are designed to instill in our graduates the skills appropriate to their professions and life-long learning. The EE program uses the term **student learning outcomes** to describe knowledge and skills at the time of graduation that are derived from the objectives.

Holistic Education: Electrical Engineering graduates shall be prepared to practice the profession of engineering using a systems perspective broad enough to encompass technological, economic, ethical, environmental, social, and human issues, shall have demonstrated a facility for independent learning, and shall be prepared for continued professional development.

- H1: Demonstrate a facility for independent learning
- H2: Be prepared for continued professional development
- H3: Effective communications skills
- H4: Contemporary Issues
- H5: Role of professional in global society

Technical Preparation: Electrical and Computer Engineering graduates shall demonstrate technical depth and breadth in their discipline.

- T1: General engineering science core plus a discipline-specific technical core
- T2: Effective use of contemporary tools of the engineering profession

Design & Professional Practice: Electrical Engineering graduates shall have participated in design experiences including a comprehensive, industrially-oriented design project, oral presentations, and written communications.

- D&P: Client sponsored team design experience

Electrical Engineering

Freshman Year

Fall Term				Credit
PH	111	Physics I		4
MA	111	Calculus I		5
CLSK	100	College and Life Skills		1
RH	131	Rhetoric & Composition		
		or		

Sophomore Year

Fall Term				Credit
MA	221	Differential Equations and	4	
		Matrix Algebra I		
CHEM	105	Engineering Chemistry I	4	
ECE	203	DC Circuits	4	
ECE	230	Microcontrollers and	4	

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

HSS		Elective	4		Computer Architecture	
ECE	160	Engineering Practice	2			6
			16			
<i>Winter Term</i>			<i>Credit</i>	<i>Winter Term</i>		
PH	112	Physics II	4	MA	222	Differential Equations & Matrix Algebra II
MA	112	Calculus II	5			Math/Science Elective
ECE	130	Introduction to Logic Design	4	ECE	204	AC Circuits
RH	131	Rhetoric & Composition or		HSS		Elective
HSS		Elective	4			16
			17	<i>Spring Term</i>		
<i>Spring Term</i>			<i>Credit</i>	<i>Credit</i>		
PH	113	Physics III	4	MA	381	Introduction to Probability with Applications to Statistics
MA	113	Calculus III	5	ECE	205	Dynamical Systems
HSS		Elective	4	ECE	250	Electronic Device Modeling
CSSE	120	Introduction to Software Development	4	HSS		Elective
			17			16
Junior Year				Senior Year		
<i>Fall Term</i>			<i>Credit</i>	<i>Fall Term</i>		
ECE	300	Signals & Systems	4	ECE	460	Engineering Design I
ECE	370	Power & Energy Systems or				Tech Elective
ECE	371	Sustainable Energy Systems	4			Area Elective
ECE	340	Electromagnetic Fields	4	HSS		Elective
RH	330	Technical and Professional Communication	4			15
			16	<i>Winter Term</i>		
<i>Winter Term</i>			<i>Credit</i>	<i>Credit</i>		
ECE	380	Discrete Time & Continuous Systems	4	ECE	461	Engineering Design II
ECE	351	Analog Electronics	4			Tech Elective
ECE	341	Electromagnetic Waves	4			Area Elective
		Math/Science Elective	4	HSS		Elective
			16			16
<i>Spring Term</i>			<i>Credit</i>	<i>Spring Term</i>		
ECE	310	Communications Systems	4	ECE	462	Engineering Design III
ECE	320	Linear Control Systems	4			Free Elective
ECE	333	Digital Systems	4			Free Elective
ECE	362	Principles of Design	3			Area Elective
				HSS		Elective
						18
				Total credits required: 194		

Area Electives

An area elective course is

- 1. Any course bearing an ECE prefix at the 400 level or above.
- 2. All area electives must bear an ECE prefix at the 400 level or above.

Tech Elective

- 1. Any course NOT bearing a GS, RH, IA, SV, GE, JP, and SP prefix

Notes:

- 1. MA 351-356 Problem Solving Seminar may not be combined and substituted for the math elective.
- 2. EE seniors are strongly encouraged to take MA 371 Linear Algebra I or MA 373 Applied Linear Algebra for Engineers
- 3. EE majors are not permitted to take ECE 206 Elements of Electrical Engineering, or ECE 207 Electrical Engineering as free electives or technical electives. Free electives may be selected from any other R-HIT courses.
- 4. EE majors may take any additional math, biology, chemistry, or physics courses as a math science elective except those courses that are cross-referenced with any engineering courses.

Core Courses

Course Number	Course Title	Credits
ECE130	Introduction to Logic Design	4
ECE160	Engineering Practice	2
ECE203	DC Circuits	4
ECE204	AC Circuits	4
ECE205	Dynamical Systems	4
ECE230	Microcontrollers and Computer Architecture	4
ECE250	Electronic Device Modeling	4
ECE300	Signals & Systems	4
ECE310	Communication Systems	4
ECE320	Linear Control Systems	4
ECE333	Digital Systems	4
ECE340	Electromagnetic Fields	4
ECE341	Electromagnetic Waves	4
ECE351	Analog Electronics	4
ECE362	Principles of Design	3
ECE370 or ECE371	Power & Energy Systems or Sustainable Energy Systems	4
ECE380	Discrete Time & Continuous Systems	4
ECE460	Engineering Design I	3
ECE461	Engineering Design II	4
ECE462	Engineering Design III	2

Second Major in Electrical Engineering

The ECE Department will not allow the following second major combinations:

- 1. Degree in Electrical Engineering and a Second Major in Computer Engineering.
- 2. Degree in Computer Engineering and a Second Major in Electrical Engineering.

Other students outside of ECE can get a second major in EE by completing all of the courses in a required plan.

EE Second Major

Course Number	Course Name	Credits
ECE 130	Introduction to Logic Design	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4

ECE 230	Microcontrollers and Computer Architecture	4
ECE 250	Electronic Device Modeling	4
ECE 300	Signals & Systems	4
ECE 310	Communication Systems	4
ECE 320	Linear Control Systems	4
ECE 333	Digital Systems	4
ECE 340	Electromagnetic Fields	4
ECE 341	Electromagnetic Waves	4
ECE 351	Analog Electronics	4
ECE 370	Power & Energy Systems	4
or		
ECE 371	Sustainable Energy Systems	4
ECE 380	Discrete Time & Continuous Systems	4
Total		60

Area Minor in Electrical and Computer Engineering

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Fred Berry

Requirements for Area Minor in ECE

- ECE203
- ECE204
- Plus four additional ECE courses, except EC160, ECE361, ECE362, ECE460, ECE461, ECE462, ECE466, ECE206, and ECE207

Example Area Minor for Physics and Optical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE205	Dynamical Systems	4
ECE300	Signals and Systems	4
ECE380	Discrete Time and Continuous Systems	4
ECE310	Communication Systems	4

Example Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits
ECE130	Introduction to logic Design	4
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4
ECE333	Digital Systems	4

Example Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203 Required	DC Circuits	4
ECE204 Required	AC Circuits	4
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy Systems	4
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

Areas of Concentration

Concentration In Energy Production, Utilization, And Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that

broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE 561 Air Pollution
- CE 590 Climate Change Assessment
- CHE 490 Energy and the Environment
- CHE 512 Petrochemical Processes
- ECE 370 Power & Energy Systems
- ECE 371 Sustainable Energy Systems
- ME 407 Power Plants
- ME 408 Renewable Energy

Enhanced Study in Communication Systems

Communications Concentration (intended for students majoring in EE or CPE)

ECE 310 Communication Systems plus any three courses from the list

- ECE 410 Communication Networks
- ECE 412 Software Defined Radio
- ECE 414 Wireless Systems
- ECE 415 Wireless Electronics
- ECE 418 Fiber Optic Systems
- ECE 510 Error Correcting Codes
- ECE 511 Data Communication
- ECE 553 Radio-Frequency Integrated Circuit Design

Communications Certificate (intended for students majoring in EE or CPE)

- ECE 300 Signals and Systems
- ECE 380 Discrete-Time Signals and Systems
- ECE 310 Communication Systems
- MA 381 Introduction to Probability with Applications to Statistics

plus any four courses from the above Communications Concentration list.

Area Minor in Communications (Area Minor in ECE with a Communications Focus)(intended for students not majoring in EE or CPE)

- ECE203 DC Circuits
- ECE204 AC Circuits
- ECE205 Dynamical Systems
- ECE300 Signals and Systems
- ECE310 Communication Systems

plus one additional course from the above Communications Concentration list.

Enhanced Study in Power Systems

Power Certificate

Take all of the following courses:

- ECE 571 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
- ECE 471 Industrial Power Systems, Pre: ECE 370
- ECE 470 Power Systems I, Pre: ECE 370
- ECE 371 Sustainable Energy Systems ,Pre: ECE 204
- ECE 370 Power & Energy Systems, Pre: ECE 204
- ECE 204 AC Circuits, Pre: ECE203 with a grade of C or better and PH113

ECE 203 DC Circuits, Pre: MA111 and PH112

Optical Communications Certificate

Faculty advisors: B. Black and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is well suited to the students at Rose-Hulman. All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Physics

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

Engineering Physics Program Educational Objectives and Outcomes:

In concurrence with the mission statement of the department the objective of the engineering physics program will produce graduate who will, 5 years after graduation, exhibit the following characteristic traits as a practicing engineer.

All engineering physics students will be prepared for initial employment, graduate school, or volunteer service and will meet the following objectives.

They will:

1. Exhibit strong skills in problem solving, leadership, teamwork, and communication.
2. Use these skills to contribute to their community and globally.
3. Make thoughtful, well-informed choice in their projects and career.
4. Demonstrate commitment to continuous education of themselves and of others.
5. Be effective multi-disciplinary engineers/researchers (in their area of concentration) and problem solvers and be life long learner.
6. Be educated in the principles of sciences and engineering necessary to understand systems in their

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)
Biochemistry & Molecular Biology (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

- concentration.
7. Be able to use engineering tools that will allow them to design, analyze, and test systems.
 8. Be able to communicate effectively in oral, written, and graphical communications as needed in a multidisciplinary team..
 9. Be aware of the impact of their work in local and global environment.

By the time students graduate with an engineering physics degree from Rose-Hulman, we expect them to possess the following:

- Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering
- Interpreting Data: Ability to interpret graphical, numerical, and textual data.
- System Level Modeling: Ability to model components and optical system engineering problems.
- Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.
- Design: Ability to design a product or process to satisfy client's needs subject to constraints
- Team work and Deliverables: Ability to work in multi-disciplinary teams and understand the effective team dynamics and be able to deliver a product.
- Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world optical engineering problems.
- Professional Practice and Ethics: A sound understanding what an optics professional is and have an awareness and understanding of professional ethics.
- Communication: Ability to communicate effectively in oral, written and visual forms.
- Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Life Long Learning: A facility for independent learning and continued professional development.

Engineering Physics (Micro - Nano)

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College and Life Skills	1
RH 131	Rhetoric and Composition	4
EM 104	Graphical Communications	2
		16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 105	Engineering Chemistry I	4
CSSE 120	Introduction to Software Development	
OR		
ME 123	Computer Applications I..	4
		17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
CHEM 107	Engineering Chemistry II	4
OE 172	Optics in Technology*	2
EM 103	Introduction to Design**	2

Sophomore Year

Fall Term		Credit
ES 201	Conservation and Accounting Principles	4
PH 235	Many Particle Physics	4
MA 221	Differential Equations I	4
PH 292	Physical Optics	4
		16

Winter Term		Credit
EP 280	Intro to Nano Engineering	4
PH 255	Foundations of Modern Physics	4
MA 222	Differential Equations II	4
ES 202	Fluid & Thermal Systems	3
		15

Spring Term		Credit
HSS	Elective	4
OE 295	Optical Systems	4
SL 151	Principles of Economics	4
ES 203	Electrical Systems	4

		16
--	--	----

2

17*

Junior Year

Fall Term

			Credit
PH	316	Electric and Magnetic Fields	4
HSS		Elective	4
PH	405	Semiconductor Materials and Applications	4
MA	223	Engineering Statistics I	4
			16

Winter Term

			Credit
HSS		Elective	4
PH	317	Electromagnetism	4
RH	330	Technical and Professional	4
EP	406	Communication.. Semiconductor Devices and Fabrication	4
			16

Spring Term

			Credit
EP	380	Nanotechnology, Entrepreneurship and	4
EP	410	Ethics	4
EP	415	Intro to MEMS Engineering Physics Project I	4
EP	408	Engineering Elective or Microsensors	4
			16

Senior Year

Fall Term

			Credit
EP	416	Engineering Physics Project II	4
EP	411	Advanced topics in MEMS	4
OE	495	Optical Metrology Engineering Elective	4
			16

Winter Term

			Credit
EP	417	Engineering Physics Project III	4
HSS		Elective	4
		Elective	4
PH	401	Intro Quantum Mechanics	4
			16

Spring Term

			Credit
HSS		Elective	4
HSS		Elective	4
		Science Elective	4
		Engineering Elective or	
EP	408	Microsensors	4
			16

Total credits required: 193

*If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

**Students need to take either EM 103 Introduction to Design or ECE 361 Engineering Practice.

EP 415, EP 416, and EP 417 are courses the student can take from any engineering department where the student has an area of concentration. The projects will have industrial clients that emphasize both physics and engineering and it may be jointly administered with the respective departments.

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

Subjects	#Classes	Hours
Physics (PH)	10	40
Math (MA)	6	27
Chemistry (CHEM)	2	8

Computer Science (CSSE)/ME	1/0 or 0/1	4
EM	2	4
CLSK	1	1
Engineering Science	3	11
Optical Engineering (OE)	3	10
HSS	9	36
Engineering Physics (EP)	6	24
Engineering Physics Projects (EP)	3	12
Elective (Science, Eng. and Free)	4	16
Total	50	193

Summary of Graduation Requirements for Engineering Physics

- 1. All the courses listed above by the number.
- 2. The program must be approved by the EP advisor.
- 3. A list of the engineering electives is provided.
- 4. An engineering elective is any RHIT course in an engineering discipline.
- 5. Science electives are courses that should be taken in the physics, chemistry, math, or biology programs.
- 6. A free electives is any course in engineering, science, humanities, military science, or air science.

Classes by Subjects

	Hours
Physics Coursework*	
Chemistry and Mathematics Coursework**	40
Humanities and Social Science (Standard requirement)	35
Computer Science, EM, CLSK Courses	36
Engineering Science Classes	9
Other Engineering Classes (Optical)	11
EP Courses	10
EP Projects	24
Engineering Electives	12
Science and Free Electives	8
Total	193

Foundation Physics Classes

Course	Description	Hours
PH 235	Many Particle Physics	4
PH 255	Foundations of Modern Physics	4
PH 316	Electric & Magnetic Fields	4
PH 317	Electromagnetism	4
PH 401	Introduction to Quantum Mechanics	4
Total		20

General Foundation Classes

Course	Description	Hours
PH 111	Physics I	4
PH 112	Physics II	4
PH 113	Physics III	4
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 221	Differential Equations & Matrix Algebra I	4

MA 222	Differential Equations & Matrix Algebra II	
MA 223	Engineering Statistics	4
CHEM 105	Engineering Chemistry I	4
CHEM 107	Engineering Chemistry II	4
Total		47

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	
OE 172	Optics in Technology	2
ES 201	Conservation and Accounting Principles	2
ES 202	Fluids and Thermal Systems	4
ES 203	Electrical Systems	3
EP 280	Introduction to Nano-engineering	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 408	Microsensors	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
	Advance Topics in MEMS	4
EP 411	Optical Metrology	4
OE 495	Engineering Elective	4
		8
CSSE 120/	Computer Programming	
ME 123		4
Total		67

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Recommended Engineering Electives: Requires the approval of the advisor.

The EP advisory committee can modify this list and add more courses over time.

- ECE 204 AC Circuits
- ECE 205 Dynamic Systems
- ECE 351 Analog Electronics
- ME 424 Composite Materials & Mechanics
- OE 485 Electro-Optics & Applications
- OE 450 Laser Systems
- ME 328 Engineering of Materials
- CHE 315 Materials Science & Engineering
- EP 440/407* Advanced Materials

* indicates a course that is under development.





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Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Mathematics

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

Program Goals and Objectives

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

Degree Requirements

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements: All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics courses. In addition, a mathematics major must complete 8 credit hours of either a senior thesis or project, meant as a capstone experience to the major. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA190, MA351-MA356, MA450 or MA223 (unless approved by the department head). These courses (except MA190) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core	39 hrs.
MA 111, 112, 113 Calculus I, II, III	15 hrs.
MA 221, 222 Differential Equations and Matrix Algebra I, II	8 hrs.
MA 275 Discrete and Combinatorial Algebra I	4 hrs.
MA 366 Functions of a Real Variable	4 hrs.
MA 371 Linear Algebra I	4 hrs.
MA 381 Introduction to Probability with Applications to Statistics	4 hrs.

Mathematics Concentration Core	12 hrs.
Three courses selected as follows:	
MA 367 Functions of a Complex Variable	4 hrs.
MA 376 Abstract Algebra	4 hrs.
One of the following	4 hrs.
MA 433 Numerical Analysis	
MA 436 Introduction to Partial Differential Equations	
MA 446 Combinatorial Optimization	
MA 481 Introduction to Mathematical Statistics	

Continuous Applied Mathematics Concentration Core	12 hrs.
--	----------------

Three courses selected per the list below. Students completing the Continuous Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core **12 hrs.**

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives **12 hrs.**

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- MA 493 and MA 494 must be taken in separate terms.
- The requirement of MA 491-492 may be fulfilled through some project experience (such

as an internship) and another 300-level or above mathematics course (4 hours), as approved by the project advisor. The course substitution procedure must be used.

- The project must involve work done by the student(s) to solve a problem presented by an external sponsor. The written project submission must be signed by the student's project advisor (who must be a member of the mathematics department) and two additional members (who are approved by the project advisor), and must be presented publicly to the department. The additional members of the committee may include representatives of the sponsor.

Senior Thesis Option: Students seeking to do a senior thesis must complete a written thesis involving effort equivalent to the 8 credit hours of MA496 – MA 498. Specifically,

- MA 497 and MA 498 must be taken in separate terms.
- The requirement of MA 496 may be fulfilled through some undergraduate research experience and an additional 300-level or above mathematics course (4 hours), as approved by the thesis advisor. The course substitution procedure must be used.
- The thesis must involve creative work done by the student and a significant portion of this work must have been done by the student individually (not as part of a team). The written submission must be signed by the student's thesis advisor (who must be a member of the mathematics department) and two additional faculty members (who are approved by the thesis advisor), and must be presented publicly to the department.

Summary of Requirements

Mathematics Coursework - core, concentration and electives (MA351-MA356, MA450 not allowed)	63 hrs.
Mathematics Senior Project/Thesis	8 hrs.
MA 190 - Contemporary Mathematical Problems (primary major only)	2 hrs.
Physical and Life Sciences*	24 hrs.
Computer Science**	8 hrs.
Humanities and Social Science (standard requirement)	36 hrs.
Technical Electives***	24 hrs.
Free Electives	28 hrs.
Miscellaneous****	1 hr.
<hr/>	
Total hours required for graduation	194 hrs.

* PH 111, 112, and 113 — Physics I, II, and III	12 hrs.
AB 101 — Essential Biology (or higher-level AB course)	4 hrs.
CHEM 105 - Engineering Chemistry I	4 hrs.
or	
CHEM 111 — General Chemistry I	
4 additional credit hours in Physical or Life Sciences	4 hrs.
** CSSE 120 — Introduction to Software Development	4 hrs.
CSSE 220 — Object-Oriented Software Development	4 hrs.
*** 200 level or above non-mathematics coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth.	24 hrs.
**** CLSK 100 — College and Life Skills	1 hr.

Suggested Schedule

The schedule below is a suggested schedule only. Scheduling of courses may be altered, subject to approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor

or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended basic chemistry course is CHEM 105 unless a student is taking a second major or minor requiring CHEM 111 or credit for CHEM 111 has already been received. If CHEM 111 is taken instead of CHEM 105 then the order of the basic science electives in the freshman and sophomore is the second science course listed. Two science courses are to be taken in the winter quarter of freshman year

MATHEMATICS

Freshman Year

Fall Term			Credit
MA	111	Calculus I	5
PH	111	Physics I	
		or	
CHEM	111	General Chemistry I	4
RH	131	Rhetoric and Composition	
		or	
HSS		HSS Elective	4
CLSK	100	College and Life Skills	
CSSE	120	Introduction to Software Development	1
			4
			18

Winter Term			Credit
MA	112	Calculus II	5
PH	112	Physics II	
		or	
PH	111	Physics I	4
CHEM	105	Engineering Chemistry I	
		or	
AB	101	Essential Biology (or higher level AB course)	4
HSS		HSS Elective	4
RH	131	or Rhetoric & Composition	
			17

Spring Term			Credit
MA	113	Calculus III	5
PH	113	Physics III	
		or	
PH	112	Physics II	4
MA	190	Contemporary Mathematics Problems	
HSS		HSS Elective	2
			4
			15

Junior Year

Fall Term			Credit
MA		MA Elective	4
		Technical Elective	4

Sophomore Year

Fall Term			Credit
MA	221	Differential Equations I	4
MA	275	Disc. & Comb. Algebra I	
AB	101	Essential Biology (or higher level AB course)	4
		or	
PH	113	Physics III	4
CSSE	220	Object-Oriented Software Development	
			4
			16

Winter Term			Credit
MA	222	Differential Equations II	4
		Science Elective	4
		Technical Elective	4
HSS		HSS Elective	4
			16

Spring Term			Credit
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MA	381	Introduction to Probability	4
MA	371	Linear Algebra I	4
		Technical Elective	4
HSS		HSS Elective	4
			16

Senior Year

Fall Term			Credit
MA	491	Intro to Math Modeling (2 hours)	

HSS	Technical Elective		MA	492	Senior Project I (2 hours)	
	HSS Elective	4			or	
		4	MA	496	Senior Thesis I (4 hours)	4
		16			Free Elective	
<i>Winter Term</i>					Free Elective	4
			HSS		HSS Elective	4
						4
						16
MA	366	Functions of a Real				
MA		Variable				4
		MA Elective				4
HSS		Technical Elective				4
		HSS Elective				4
						16
<i>Spring Term</i>		<i>Credit</i>	<i>Winter Term</i>			
MA		MA Elective				4
MA		MA Elective				4
		Technical Elective				4
HSS		HSS Elective				4
						18
						4
						16
<i>Spring Term</i>		<i>Credit</i>	<i>Spring Term</i>			
MA	494	Senior Project III (2 hours)				
		or				
MA	498	Senior Thesis III (2 hours)				2
MA		MA Elective				4
		Free Elective				4
		Free Elective				4
		Free Elective				4
						14
						14
Total credits required: 194						

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- **Math Elective:** A course either required by the concentration or a true math elective.
- **Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- **Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics.
- **Free Elective:** Any course.

Area Minor in Mathematics

A student, not pursuing a major in mathematics, computer science, economics, or a second major in mathematics may obtain an area minor in mathematics by taking 10 or more mathematics courses as follows:

- **Six courses in foundational mathematics**
Calculus, Differential Equations and Matrix Algebra: MA 111, MA 112, MA 113, MA 221, MA 222
Basic Probability and Statistics or Basic Statistics: one of MA 223, MA 381, or MA382
- **Sixteen additional credit hours of “upper division” courses:**
Courses selected from MA 275, all MA courses numbered 300 or higher (except MA351-356 and MA450), or other MA courses approved by the area minor advisor for mathematics.

Approval and Math Minor Form

All area minors must be approved by the area minor advisor and the student's advisor. The department has a form for the planning and approval of a mathematics minor.

Notes and Limitations on Requirements:

- Almost all students are required to take six foundational courses as a requirement for their major; therefore only four "extra courses" are required for most students.
- Only MA111, MA112, MA113, MA221 and one of MA223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit
- Except as noted above, if MA 381 is being counted towards the four additional courses then, MA 223 may be taken and counted towards the Basic Probability and Statistics.
- Science and engineering, especially the most recent "high tech" developments, have sophisticated mathematical and statistical concepts and methodologies as their foundation. Thus a well chosen set of courses for a mathematics minor (or a second major in mathematics) will greatly enhance a student's analytical and computational skills. Students thinking of going on to graduate school should especially give consideration to this option.

AREA MINOR IN COMPUTATIONAL SCIENCE

Any student may obtain an area minor in Computational Science by taking the following courses:

- Five courses in foundational mathematics: MA111, MA112, MA113, MA221, MA222
- Basic computing course: CSSE 120 or departmental equivalent of at least 4 credit hours
- Introductory Computational Science courses:
 - MA332 Introduction to Computational Science
 - MA342 Computational Modeling
- Four credit hours of applied Computational Science course from list A
- Four credit hours of additional Computational Science course from list B

List A: Applied Computational Science courses

- MA323 – Geometric Modeling
- MA439 – Mathematical Methods of Image Processing
- MA444 – Deterministic Models in Operations Research
- CSSE351 – Computer Graphics
- CSSE451 - Advanced Computer Graphics
- CSSE413 – Artificial Intelligence
- CSSE453 – Topics in Artificial Intelligence
- CSSE461 – Computer Vision
- CSSE463 - Image Recognition
- CE522 - Advanced Finite Element Analysis
- ME422 – Finite Elements for Engineering Applications
- ME427 - Introduction to Computational Fluid Dynamics
- ME511 - Numerical Methods for Dynamic Systems Analysis
- ME522 - Advanced Finite Elements Analysis
- 4XX – Introduction to MEMS: Fabrication and Applications
- 5XX – Advanced Topics in MEMS
- CHE521 – Advanced Chemical Engineering Computation
- BE510 – Biomedical Signal and Image Processing
- EMGT526 - Technology Forecasting
- MA534/EMGT534 - Management. Science
- ECE420 - Nonlinear Control Systems
- ECE480//PH437 – Introduction to Image Processing
- ECE582/PH537 – Advanced Image Processing
- ECE483 - DSP System Design

List B: Additional Computational Science courses

- MA/CSSE335 - Introduction to Parallel Computing
- MA433 - Numerical Analysis
- MA434 – Topics in Numerical Analysis
- MA348 - Continuous Optimization
- MA446 - Combinatorial Optimization

- CSSE304 - Programming Language Concepts
- CSSE371 - Software Requirements and Specification

Electives not on list A or B may be substituted with other courses with the approval of the area minor advisor.

The minor must be approved by the area minor advisor for Computational Science and the student's advisor. The department has a form for the planning and approval of a minor.

Notes and limitations on requirements

- Almost all students are required to take the five foundational courses as a requirement for their major
- Most majors should be able to apply the basic computing requirement and/or one of the elective courses towards their major.
- Math majors or double majors are **not** allowed to count MA332 and MA342 for both the minor and the major.
- A student may **not** apply the four upper-division courses toward both this minor and a math or statistics minor.

Area Minor in Statistics

A student, not pursuing a major or second major in mathematics may obtain an area minor in statistics by taking ten or more mathematics courses (40 credit hours) including the following:

- **Globally required mathematics courses**
 - MA 111 Calculus I
 - MA 112 Calculus II
 - MA 113 Calculus III
 - MA 221 Differential Equations and Matrix Algebra I
- **Required Introductory Statistics/Probability Courses:**
 - MA 381 Introduction to Probability with Applications to Statistics,
 - One of MA223 Engineering Statistics I or MA382 Introduction to Statistics with Probability. If MA 381 is taken before MA223/MA382 the student will be strongly recommended to take MA382.
- **Required Second Statistics Course**
 - One of MA383 Engineering Statistics II or MA482 Bioengineering Statistics
- **Electives**
 - 3 courses (12 credits) selected from the following list, at least two of which must be starred.
Statistics courses not on this list may count towards the minor if approved by statistics area minor advisor.
 - MA 385* Quality Methods
 - MA 386* Statistical Programming
 - MA 387* Statistical Methods in Six Sigma
 - MA 371 Linear Algebra or MA373 Applied Linear Algebra for Engineers
 - MA 445 Stochastic Models in Operations Research
 - MA 481* Mathematical Statistics
 - MA 485* Regression and Time Series Analysis
 - MA 487* Design of Experiments
 - MA 480* Topics in Probability and Statistics

All area minors in Statistics must be approved by the statistics area minor advisor and the student's advisor. The department has a form for the planning and approval of a statistics minor.

Notes and Limitations on Requirements

- Almost all students are required to take the four globally required mathematics courses plus one probability or statistics course as a requirements for their major, therefore only five "extra courses" are required for most students
- Only MA111, MA112, MA113, MA221 and one of M223, MA381, or MA382 can be counted towards both a statistics minor and a mathematics minor.
- No student can take both MA 371 and MA 373 for credit.
- No student can take both MA223 and MA382 for credit.



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Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Mechanical Engineering

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Since mechanical engineering is a broad field of endeavor, the curriculum offers a strong technical elective program to allow each student to craft a broad educational experience and to develop the flexibility to pursue diverse career goals.

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Systems Design.

The strength of any department is its faculty. The mechanical engineering faculty are committed to providing a dynamic and innovative learning environment and to maintaining and increasing their technical competence in a rapidly changing world. Stereotypes notwithstanding, they understand that people are more important than things. Thus, they encourage each student to seek them out when he or she has academic problems or needs guidance in career planning.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 12 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mechanical Engineering Program Educational Objectives and Outcomes

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

Vision: To graduate the best baccalaureate mechanical engineers.

Mechanical Engineering Program Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. In the early phase of their careers, we expect our students to:

1. Apply engineering fundamentals to problem solving processes in an iterative manner.
2. Design effectively.
3. Continue to learn and educate themselves.
4. Communicate effectively.
5. Work responsibly.
6. Work effectively.

Outcomes

By the time a student graduates with a mechanical engineering degree from Rose-Hulman, they will possess the following abilities:

- Ethics – A recognition of ethical and professional responsibilities
When given the opportunity, students will:
 1. Demonstrate knowledge of professional codes of ethics.
 2. Evaluate the ethical dimensions of professional engineering, mathematical, and scientific practices.
- Contemporary Issues - An understanding of how contemporary issues shape and are shaped by mathematics, science, & engineering
When applying the principles of mathematics, science, and/or engineering to a technical problem, students will:
 1. Demonstrate an awareness of how the problem is affected by social concerns and trends.
 2. Demonstrate an awareness of how the proposed solution(s) will affect culture and the environment.
- Global - An ability to recognize the impact of global societies on citizens and professionals
When given the opportunity, students will:
 1. Demonstrate an awareness of the development of cultures and societies.
 2. Show an awareness of the relationships of nations and the interdependence of peoples around the globe.
- Culture - An ability to understand diverse cultural and humanistic traditions
When given the opportunity, students will:
 1. Perform, interpret, analyze or otherwise engage in artistic, literary, and/or other forms of culture.
 2. Recognize the importance of contributions of peoples from other cultures to the students' professions and personal lives.
 3. Evaluate an issue or problem from other cultural perspectives.
- Teams - An ability to work effectively in teams
When assigned to teams, students will:
 1. Share responsibilities and duties, and take on different roles when applicable.
 2. Analyze ideas objectively to discern feasible solutions by building consensus.
 3. Develop a strategy for action.
 4. Listen openly, actively and critically.
- Communication - An ability to communicate effectively in oral, written, graphical, and visual forms
When performing communication tasks, students will:
 1. Identify the readers/audience, assess their previous knowledge and information needs, and organize/design information to meet those needs.
 2. Provide content that is factually correct, supported with evidence, explained with sufficient detail, and properly documented.
 3. Test readers/audience response to determine how well ideas have been relayed.
 4. Submit work with a minimum of errors in spelling, punctuation, grammar, and usage.
 5. Present information visually using drawings, graphs and sketches.
 6. Deliver oral presentations with clarity and professionalism.
- Problem Solving - An ability to apply the skills and knowledge necessary for mathematical, scientific, and engineering practices
 1. Inspect and define the problem.
 2. Identify the basic principles and concepts that apply to the situation.
 3. Use appropriate resources to locate pertinent information.
 4. Build appropriate model(s)

- 5. Solve the problem by choosing appropriate tools. (analytical, experimental, and numerical)
- 6. Check a solution using appropriate criteria.
- Interpreting Data - An ability to interpret graphical, numerical, and textual data
 - 1. Collect and present data in an accurate and orderly way.
 - 2. Use appropriate statistical procedures to analyze and evaluate the information contained in a data set.
 - 3. Analyze the data and draw supportable conclusions from the result.
- Experiments - An ability to design and conduct experiments
 - 1. Identify the problem and develop a hypothesis.
 - 2. Select measurement techniques to collect appropriate data and justify that selection.
 - 3. Estimate experimental uncertainties.
- Design - An ability to design a product or process to satisfy a client's needs subject to constraints
 - 1. Understand the problem.
 - 2. Develop a design specification that addresses customer/client needs and constraints.
 - 3. Carry out a conceptual design by generating multiple solutions that address the issues above, evaluating the feasibility of the solutions, and choosing the appropriate solution.
 - 4. Carry out a detail-level design using appropriate design tools and methodologies.
 - 5. Test and refine the implementation until the product or process design specifications are met or exceeded.
 - 6. Document the finished product or process as appropriate for the discipline according to standard practice.
 - 7. Present and transfer the product or process and documentation to the client.
- Continue to Learn and Educate One's Self
 - 1. Learn new information independently.

Area Minor† in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
ES 202 Fluid & Thermal Systems
or
- ME 201 Thermodynamics
EM 301 Fluid Mechanics
or
- CHE 201 Conservation Principles & Balances
CHE 301 Fluid Mechanics

(2) One of the following foundational prerequisites.

- ME 301 Thermodynamics II
- CHE 303 Chem. Engineering Thermodynamics
- ME 302 Heat Transfer
- CHE 314 Heat Transfer

(3) Three of the thermal-fluids electives listed below.

Thermal Fluid Systems

- ME 407 Power Plants†
- ME 408 Renewable Energy
- ME 409 Air Conditioning*
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems†
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 402 Advanced Heat Transfer*
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics†
- ME 502 Topics in Heat Transfer*

- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

Successful completion of an area minor is indicated on the student's transcript. A student interested in pursuing an area minor in mechanical engineering should consult with the chairman of the Department of Mechanical Engineering.

†Requires one of the thermodynamics prerequisites from section 2 above.

* Requires one of the heat transfer prerequisites from section 2 above.

‡ ME Majors do not qualify for ME Area Minors, but may pursue ME Concentrations.

Areas of Concentration

Advanced Transportation Concentration—To better prepare our students for the interdisciplinary field of Advanced Transportation, an area of concentration is offered to expose students to modern automotive, aviation, and off-highway design methodologies and technologies. Two courses in Model-Based System Design, the modern design practice in the aviation and automotive industry, is required of all participants. Three additional elective courses are required which permit students to provide either depth or breadth according to their interests.

Required Courses

- CE/ME 497 Introduction to Model-Based System Design
- ECE/ME 497 Advanced Model Based-System Design

Elective Courses

- CHEM 470 Combustion Chemistry
- ECE 320 Linear Control Systems
or
ME 406 Control Systems
- ECE 420 Nonlinear Control Systems
or
ME 506 Advanced Control Systems
- ECE 370 Machines & Power
- ECE 410 Communication Networks
- ECE 452 Power Electronics
- ME 408 Renewable Energy
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 422 Finite Elements for Engineering Applications
- ME 427 Introduction to Computational Fluid Dynamics

Aerospace Engineering Area of Concentration

The aerospace industry provides job opportunities each year for many mechanical engineering graduates. The aerospace engineering area of concentration is intended to provide specialty courses which focus the application of basic mechanical engineering skills on aerospace systems.

The courses required to complete the concentration are as follows:

- ME 305 Introduction to Aerospace Engineering

Plus any 4 of the following

- MA 336 Boundary Value Problems
- ME 405 Theoretical Aerodynamics
- ME 401 Foundation of Fluid Mechanics
- ME 411 Propulsion Systems
- ME 422 Intro to Finite Element Fundamentals
- ME 427 Introduction to Computational Fluid Dynamics
- ME 461 Aerospace Design
- ME 503 Viscous Flow
- ME 510 Gas Dynamics

- ME 512 Light Weight Structures
- ME 522 Advanced Finite Element Analysis
- PH 322 Celestial Mechanics

Any student who completes these requirements may receive, on request, a letter from the Department Head attesting to the fact that the student has completed the requirements in the aerospace engineering area of concentration in the Mechanical Engineering Department. With proper planning, students should be able to complete the concentration without overload. Additional courses may satisfy the concentration with Department Head approval.

Energy Production, Utilization, and Forecasting

Rising energy costs, air pollution, climate change, petrochemical production, environmental friendly and green processes and machines, alternative power sources and renewable energy are some of the topics topping local, national and international news. Rose-Hulman offers a series of courses, across several disciplines that broadens, educates and addresses solutions to these relevant contemporary issues.

Students who complete any five of the recommended courses in Energy Production, Utilization, and Forecasting area of concentration may receive, upon request, a letter from their Department Head, a certificate and transcript annotation attesting to the fact that the student has completed the requirements in this area of concentration in the Energy Production, Utilization, and Forecasting. With proper planning, students should be able to take these course offerings without overload.

Recommended Energy Production, Utilization, and Forecasting Concentration Courses.

- CE561 or CHE450 Air Pollution (cross-listed class)
- CE590 Climate Change Assessment
- CHE490 Energy and Environment
- CHE512 Petrochemical Processes
- ECE370 Power and Energy Systems
- ECE371 Industrial Power Systems
- ME407 Power Plants
- ME408 Renewable Energy
- ME501 Advanced Thermodynamics

Industrial Leadership

Many mechanical engineering students are attracted to industry for both technical and leadership opportunities. Graduates often are responsible for project management and may develop over time into more significant leadership roles. This area of concentration is intended to take advantage of Rose-Hulman offerings in Mathematics, Engineering Management, and Humanities and Social Sciences to provide skills and knowledge that would be useful for graduates with increasing managerial responsibilities. Since part of leadership is also practice, the area of concentration requires one industrial internship and one significant leadership experience.

To complete the requirements of the area of concentration in industrial leadership, each student must take a total of six courses, two from the Math list, two from the Engineering Management list, and two from the Humanities, Social Sciences list

Math List

- MA 385 Quality Methods
- MA 487 Design of Experiments
- MA 387 Statistical Methods in Six Sigma

Engineering Management List

- EMGT330 Introduction to Engineering Management
- EMGT427 Project Management
- EMGT520 Accounting for Technical Managers
- EMGT521 Financial Management in a Technical Environment
- EMGT522 Organizational Management
- EMGT523 Marketing Issues in a Technical Environment 4
- EMGT524 Production/Operations Management
- EMGT526 Technology Management and Forecasting
- EMGT527 Project Management
- EMGT531 Economics for Technical Managers
- EMGT532 Technical Entrepreneurship

- EMGT533 Intercultural Communication
- EMGT534 Management Science
- EMGT535 Strategies for Organizational Change
- EMGT586 Supply Chain Management
- EMGT587 Systems Engineering
- EMGT588 Quality Management I
- EMGT589 Manufacturing Systems

Humanities, Social Sciences List

- GS 350 International Trade
- GS 351 International Finance
- IA 230 Fundamentals of Public Speaking
- SV 151 Principles of Economics
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- IA 352 Game Theory
- SV 303 Business and Engineering Ethics
- SV 304 Bioethics
- SV 352 Money & Banking
- SV 353 Industrial Organization
- SV 354 Environmental Economics
- SV 356 Corporate Finance
- EMGT 526 Technology Management and Forecasting

In addition to coursework, students must complete one Industrial Internship (of approximately three month duration) and one significant co-curricular leadership experience. To get credit for the leadership experience, the student must submit an application with reference support which is approved by the department head. Possible examples of qualifying leadership could include leadership experience in design-build competitions or serving as a Resident Assistant in the residence halls.

Manufacturing and Production Engineering Area of Concentration

Many mechanical engineering graduates will work in tasks related to the manufacture of various products. The manufacturing and production engineering area of concentration is intended to bridge the gap between the analytical and design courses which are the heart of the professional program and the practical problems of producing acceptable hardware, on time, at a profit.

The courses that comprise this area of concentration are:

List 1:

- EMGT 330Introduction to Engineering Management
- EMGT 427Project Management
- EMGT 588Quality Management
- EMGT 589Manufacturing Systems
- MA 385 Quality Methods
- ME 317 Design for Manufacturing
- ME 417 Advanced Materials Engineering
- ME 435 Robotics
- ME 520 Computer Aided Design/Computer Aided Manufacturing

When choosing humanities and social science electives (HSS), we suggest that the following are most pertinent to the manufacturing/production working environment:

List 2:

- SV 151 Principles of Economics
- SV 171 Principles of Psychology
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 353 Industrial Organization
- IA 453 The Entrepreneur
- SV 356 Corporate Finance

With proper planning, students should be able to take the elective offerings in this area without overload. Any student who completes five courses from List 1 and three of the recommended HSS courses from List 2 may receive, upon request, a letter from the Department

Head attesting to the fact that the student has completed the requirements in the manufacturing and production engineering area of concentration in the Mechanical Engineering Department.

Solid Mechanics Area of Concentration

The broad field of solid mechanics prepares the mechanical engineering graduate with many career opportunities in areas such as stress analysis, dynamics, vibrations, materials, and the design of mechanical components and systems.

The courses that comprise this area of concentration are:

- ME 417 Advanced Materials Engineering
- ME 422 Intro. Finite Element Fund.
- ME 512 Light Weight Structures
- ME 513 Environmental Noise
- ME 518 Advanced Kinematics
- ME 522 Advanced Finite Element Analysis
- EM 403 Advanced Mechanics of Materials
- EM 406 Vibration Analysis
- EM 502 Advanced Dynamics
- EM 503 Advanced Vibration Analysis
- EM 505 Theory of Elasticity

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the solid mechanics area of concentration within the Mechanical Engineering Department.

Thermal Fluid Area of Concentration

Many Mechanical Engineering graduates will work with engineering systems that are based on the principles of thermodynamics, heat transfer and fluid mechanics. The Mechanical Engineering curriculum offers an opportunity for the student to concentrate his studies on the analysis and design of these systems. The courses that comprise the thermal fluid area of concentration may be classified according to whether the main emphasis is on the system or on the thermal or fluid concepts which underpin its design and operation.

Thermal Fluid Systems

- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 409 Air Conditioning
- ME 410 Internal Combustion Engines
- ME 411 Propulsion Systems
- ME 426 Turbomachinery

Thermal Fluid Sciences

- ME 402 Advanced Heat Transfer
- ME 405 Theoretical Aerodynamics
- ME 427 Computational Fluid Dynamics
- ME 501 Advanced Thermodynamics
- ME 502 Topics in Heat Transfer
- ME 503 Viscous Fluid Flow
- ME 510 Gas Dynamics
- EM 501 Topics in Fluid Mechanics

In order to complete the requirements in the thermal fluid area of concentration a student must select five elective from the lists such that at least one course is taken from the “Thermal Fluid Systems” list and at least two courses are taken from the “Thermal Fluid Sciences” list.

With proper planning, students should be able to take five elective courses in the area without overload. Any student who completes five of these recommended courses may request a letter from the Department Head attesting to the fact that the student has completed the requirements in the thermal fluid area of concentration within the Mechanical Engineering Department.

MECHANICAL ENGINEERING

Freshman Year

Fall Term			Credit
MA	111	Calculus I	5
PH	111	Physics I	4
CLSK	100	College & Life Skills	1
EM	104	Graphical Communications	2
RH	131	Rhetoric & Composition	
		split fall or winter with	
		Elective(HSS)	4
			16

Winter Term

			Credit
MA	112	Calculus II	5
PH	112	Physics II	4
ME	123	Computer Applications I	4
		Elective (HSS)	
		split fall or winter with	
RH	131	Rhetoric & Composition	4
			17

Spring Term

			Credit
MA	113	Calculus III	5
PH	113	Physics III	4
EM	103	Introduction to Design	2
EM	121	Statics and Mechanics of	
		Materials I	4
			15

Junior Year

Fall Term			Credit
ME	301	Thermodynamics II	4
EM	204	Statics and Mechanics of	4
		Materials II	
ECE	207	Elements of Electrical	4
		Engineering II	
		**Elective (Free)	4
			16

Winter Term

			Credit
ME	317	Design for Manufacturing	3

ME	321	Measurement Systems	4
		split winter or spring with	
ME	323	Computer Applications II	(2)
ME	328	Materials Engineering	4
		Elective (Science)	(4)

Sophomore Year

Fall Term			Credit
MA	221	Differential Equations I	4
ES	201	Conservation &	
		Accounting Principles	4
		Elective (HSS)	4
ES	203	Electrical Systems	4
			16

Winter Term

			Credit
MA	222	Differential Equations II	4
ES	202	Fluid & Thermal Systems	3
ES	204	Mechanical Systems	3
		Elective (HSS)	4
CHEM	105	Engineering Chemistry I	4
			18

Spring Term

			Credit
MA	223	Statistics for Engineers	4
ES	205	Analysis & Design of	
		Engineering Systems	4
CHEM	107	Engineering Chemistry II	4
		Elective (HSS)	4
			16

Senior Year

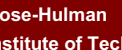
Fall Term			Credit
ME	430	Mechatronic Systems	4
		split fall or winter with	
ME	421	M.E. Lab	(2)
ME	406	Control Systems	
		or	
EM	406	Vibration Analysis	4
ME	480	Machine Component	4
		Design	
		split Jr. spring or Sr. fall with	
ME	470	Engineering Systems	(4)
		Design	
		**Elective (Tech)	4
			14 or 16

Winter Term			Credit
ME	471	Capstone Design I	2
ME	421	M.E. Lab	2

Fall			Spring		
Course	Term	Credit	Course	Term	Credit
RH 330	Technical and Professional Communication or Elective (HSS)	4	ME 430	Mechatronic Systems **Elective (Tech) **Elective (free) Elective (HSS)	4 4 4
		17 or 15			18 or 16
			<i>Spring Term</i>		
			<i>Credit</i>		
ME 302	Heat Transfer	4	ME 472	Capstone Design II **Elective (Tech)	3 4
ME 323	Computer Applications II split winter or spring with	2		**Elective (Adv Tech) Elective (HSS)	4 4
ME 321	Measurement Systems	(4)			
ME 470	Engineering Systems Design split Jr. spring or Sr. fall with	4			
ME 480	Machine Component Design Elective (Science) Elective (HSS) or	(4) 4	Total credits required: 194		
RH 330	Technical and Professional Communication	4			
		16 or 18			

* 24 credit hours. in electives composed of 16 cr. hrs. in technical electives, of which at least 4 cr. hrs. must be in advanced level courses and 8 cr. hrs. in free electives. (i.e. 12 cr. hrs. tech. electives, 4 cr. hrs. adv. tech elective, 8 cr. hrs. free electives)

**** An advanced technical elective** is designated with an * in the undergraduate bulletin ME and EM course description section or any 500 level course and above in BE, ChE, CE, CPE, EE, ME, OE or SE programs. **A technical elective** is any course (at the 200 level or above) in chemistry, computer science, engineering, engineering management, life science, mathematics, or physics that is not cross-listed with HSS or similar in content to a required course. **A science elective** is any course in applied biology, chemistry, geology or physics except those courses that are cross-referenced with an engineering course.




Rose-Hulman

Institute of Technology




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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

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Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Optical Engineering

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site:<http://www.rose-hulman.edu/phoe>

Optical Engineering Program Educational Objectives and Outcomes

Mission: To provide a coherent foundation of physics for all students and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. In the engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate a sense of responsibility, independence, and instill knowledge that allows the students to be fully engaged in all disciplines, continuously improve the curriculum through assessment, and be engaged in professional development.

The educational objectives of the optical engineering program are to prepare students to:

General Educational Objectives

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

- 1. Exhibit strong skills in problem solving, leadership, teamwork, and communication.
- 2. Use these skills to contribute to their community and globally.
- 3. Make thoughtful, well-informed choices in their projects and career.
- 4. Demonstrate commitment to continuous education (life long learners) of themselves and of others.

Core Educational Objectives

- 5. Be effective multi-disciplinary optical engineers/researchers.
- 6. Be educated in the principles of optical science and engineering necessary to understand optical systems.
- 7. Be able to use optical engineering and engineering tools that will allow them to design, build, and test systems that will incorporate optics as an enabling technology.
- 8. Be able to communicate effectively in oral, written, and graphical forms as needed in a multidisciplinary team.
- 9. Be aware of the impact of their work in local and global environment, society, and human heritage.

By the time students graduate with an optical engineering degree from Rose-Hulman, they will demonstrate:

- Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
- Interpreting Data: Ability to interpret graphical, numerical, and textual data.
- System Level Modeling: Ability to model components and system optical engineering problems.
- Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.
- Design: Ability to design a product or process to satisfy client's needs subject to constraints.
- Team Work and Deliverables: Ability to work in multi-disciplinary teams, understand the effective team dynamics and be able to deliver a product.
- Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world optical engineering problems.
- Professional Practice and Ethics: A sound understanding of what an optics professional is and have an awareness and understanding of professional ethics.
- Communication: Ability to communicate effectively in oral, written and visual forms.
- Contemporary Issues, Non-technical Issues, Global Awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
- Life Long Learning: A facility for independent learning and continued professional development.

OPTICAL ENGINEERING

Freshman Year

Fall Term			Credit
MA	111	Calculus I	5
PH	111	Physics I	4
CLSK	100	College and Life Skills	1
RH	131	Rhetoric and Composition	4
EM	104		2
		Graph Comm	
			16

Winter Term			Credit
PH	112	Physics II	4
MA	112	Calculus II	5
CHEM	105	Engineering Chem I	4
ME	123	Computer Applications I	4
			17

Spring Term			Credit
PH	113	Physics III	4
MA	113	Calculus III	5
CHEM	107	Engineering Chem II	4
OE	172*	Optics in Tech	2

Sophomore Year

Fall Term			Credit
MA	223	Engineering Statistics	
		or	
SL	151	Principles of Economics	4
PH	235	Many-Part Physics	4
MA	221	Differential Equations I	4
PH	292	Physical Optics	4
			16*

Winter Term			Credit
ECE	203	DC Circuits	4
PH	255	Fnd. of Mod. Phys.	4
MA	222	Differential Equations II	4
OE	280	Paraxial Optics	4
			16

Spring Term			Credit
		Free Elective	4
OE	295	Optical Systems	4
SL	151	Principles of Economics	
		or	

EM	103	Intro Eng. Design	2	MA	223	Engineering Statistics	4
			17	ECE	204	AC Circuits	4
							16
Junior Year				Senior Year			
Fall Term				Fall Term			
			Credit				Credit
PH	316	Elec & Mag Fields	4	OE	480	Lens Des & Abb	4
OE	360	Optical Materials and		OE	495	Optical Metrology	4
		Opto-Mechanics	4	HSS		Elective	4
PH	405	S.C. Mat & Appl.	4	OE	416	Opt Eng Des II	4
ECE	205	Dynamical Systems	4				16
			16				
Winter Term				Winter Term			
			Credit				Credit
OE	393	Fiber Opt & App	4	OE	485	Electro-Opt. & App.	4
		Free Elective	4	HSS		Elective	4
EP	406	SC Dev & Fab	4			Engineering Elective	4
HSS		Elective		OE	417	Opt Eng Des III	4
		or					16
RH	330	Technical and	4	Spring Term			
		Professional					Credit
		Communication					
			16			Engineering Elective	4
				HSS		Elective	4
				HSS		Elective	4
Spring Term						Free Elective	4
			Credit				16
OE	415		4	Total credits required: 194			
HSS		Opt Eng Des I	4				
HSS		Elective					
		Elective					
		or					
RH	330	Technical and	4				
OE	450	Professional	4				
		Communication..					
		Laser Systems					
			16				

*If OE 172 is not taken during the freshman or sophomore year, the requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

SUMMARY OF GRADUATION REQUIREMENTS FOR OPTICAL ENGINEERING

- 1. All the courses listed above by the number.
- 2. The program must be approved by the advisor.
- 3. A technical elective is any RHIT course in chemistry, computer science, engineering, life sciences, mathematics, or physics

Classes by subjects	Hours
Optics Coursework	46
Physics Coursework*	20
Freshmen Physics, Chemistry and Mathematics Coursework**	47
Humanities and Social Science (Standard requirement)	36
Electives (8 credits engineering electives, and 12 credits of free electives; cannot include ECE 340)	20
Miscellaneous***	25
Total	194

Physics Classes

Course	Description	Hours
PH235	Many particle physics	4
PH255	Foundations of Modern Physics	4
PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA221	Diff. Eq. I	4
MA222	Diff, Eq. II	4
MA223	Engineering Statistics	4
CHEM105	Engineering Chemistry I	4
CHEM107	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
EP 406	Semiconductor Devices and Fabrication	4
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
ECE 205	Dynamical Systems	4
Total		25

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials Science, and Electronics are listed below. Successful completion of an Area Minor is indicated on the student's grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Astronomy

(Eligibility: students in any major degree program)

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Hours	Course Description
PH 230	4	Introduction to Astronomy and Astrophysics
PH 240	4	Planetary Science and Cosmology
PH 310	2	Introduction to Relativity
PH 322	4	Celestial Mechanics
Plus four hours of:		
PH 270	2	Special Topics in Physics
PH 290	2	Directed Research
PH 460	4	Directed Study
PH 470	4	Special Topics in Physics
PH 490	4	Directed Research

The optional courses must be on a topic approved by one of the astronomy advisors.

Area Minor in Optical Engineering

(Eligibility: students in any degree program, except programs where Optical Engineering is designated as one of the majors.)

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required Courses

Course	Hours	Course Description
OE 280	4	Paraxial Optics
PH 292	4	Physical Optics
OE 295	4	Optical Systems

Plus at least two* courses from one of the areas listed below:

Lens Design Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 480	4	Lens Design and Aberrations
OE 490	4	Directed Research (4 Credits Only)
Photonics/Electro-optics Area		
Course	Hours	Course Description
OE 360	4	Optical Materials and Opto-mechanics
OE 415	4	Optical Engineering Design I
OE 450	4	Laser Systems and Applications
OE 485	4	Electro-optics and Applications
OE 490	4	Directed Research (4 credits only)
OE 493	4	Fundamentals of Optical Fiber Communications
Image Processing Area		
Course	Hours	Course Description
OE 415	4	Optical Engineering Design I
OE 490	4	Directed Research (4 Credits Only)
PH 437/ECE 480	4	Introduction to Image Processing
PH 537/ECE 582	4	Advanced Image Processing

In order to have the area minor posted to your transcripts you must submit an area-minor completion form to the registrar. Forms are available in the Physics and Optical Engineering department office.

Also see Certificate Program in Semiconductor Materials and Devices

Area Minor in ECE: (Eligibility: Only students in Physics and Optical Engineering)

Advisors: Optical Engineering faculty and ECE faculty

Course	Hours	Course Description
ECE 203*	4	DC Circuits
ECE 204*	4	AC Circuits
ECE 205	4	Dynamical Systems
ECE 300	4	Continuous-Time Signals and Systems
ECE 310	4	Communication Systems
ECE 380	4	Discrete-Time Signals and Systems

*required courses

In order to have the area minor posted to your transcript you must submit an area-minor completion form to the registrar. Forms are available in the Electrical and Computer Engineering office.

Optical Communications Certificate

Faculty advisors: B. Black, R. M. Bunch and S. Granieri

Rose-Hulman has become a leader in providing opportunities for students to choose a great mainstream degree program with flexibility to specialize in other areas of interest. This leadership is in no way limited to only traditional areas of study. One of these new areas that had a high impact in technology is optical communications. It is a rapidly growing field requiring investment beyond the traditional program structure, and is

well suited to the students at Rose-Hulman All these topics are closely related to well established disciplines as optics and electronics. Considerable R&D efforts are allocated in both university and industrial laboratories enhancing the demand for both researchers and engineers with expertise in the field.

We propose the creation of a new certificate program in Optical Communications to enhance the programs currently offered. Combining expertise in Optical and Electrical Engineering, this program requires an interdisciplinary emphasis that is beyond the traditional content of either of its parent programs. This program is more than just the creation of the certificate program Optical Communications. This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory. Primary objectives include the removal of redundancy from existing courses, increasing interaction between the PHOE and ECE Departments, and improving opportunities for students in the field.

This certificate is designed to give the student a firm theoretical and practical working knowledge in the area of fiber optic devices, optical communications, networks and its applications. The main purpose is to couch these fundamentals in a context that serves as the backbone for device, components and sub-system development for use in high-speed optical data and information links and networks. At the end of the program the student will be expected to:

1. Understand the fundamental operation characteristics of high speed optoelectronic components, such as laser transmitters, light modulators and receivers and passive fiber optic components as connectors, couplers, filters, and switches.
2. Understand the technology and performance of analog and digital fiber optic links, optical amplification and optical wavelength division multiplexing and optical time division multiplexing networks.
3. Have a hands-on working knowledge of the use of fiber optic test equipment and techniques used by industry and telecommunication companies to test the performance of optical fiber links and components, such as, optical time domain reflectometry, optical spectrum analyzers and optical bit error testing equipment.

The Certificate will consist of 20 credit hours of which 12 credit hours will be required courses. Students interested in pursuing this Certificate should contact an ECE/PHOE certificate advisor (Professors Black, Bunch, and Granieri)

Required Courses

- ECE 310 Communication Systems
- OE 393 Fiber Optics and Applications
- OE 493 Fundamentals of Optical Fiber Communications

Elective Courses (two from the list)

Only courses not required for the student's major will count for electives in the certificate.

- ECE 380 Discrete Time & Continuous Systems
- ECE 410 Communication Networks
- ECE 414 Wireless Systems
- OE 360 Optical Materials and Opto-mechanics
- OE 435 Biomedical Optics
- OE 450 Laser Systems and Applications
- OE 485 Electro-Optics and Applications



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Physics

The physics curriculum is designed to develop a strong foundation in classical and modern physics, which will serve as a basis for future specialization, for additional study at the graduate level, and for design and development work in industrial laboratories. The curriculum emphasizes basic physical concepts, and includes extensive work in mathematics and related areas. Laboratory facilities are available for work in optics, acoustics, X-ray diffraction, nuclear physics, and solid-state physics. Course topics included in the curriculum are Many Particle Physics, Physical Optics, Biophysics, Biomedical Optics, Theoretical Mechanics, Electromagnetism, Celestial Mechanics, Acoustics, Microsensors, Semiconductor Materials and Devices, X-rays and Crystalline Materials, Electro-Optics, and Laser Physics.

The Physics program places an emphasis on laboratory courses with a hands-on approach. The students have the opportunity to take a variety of courses in disciplines such as math and chemistry allowing them to tailor their education. The Physics curriculum is flexible enough that one can double major in computer science, mathematics, electrical engineering, and mechanical engineering. National interest in our program has been generated by our basic physics courses that use new methodologies of teaching such as studio format lectures.

We have a wide range of research programs accessible to undergraduates including areas such as: Astronomy, Solid State Devices, Electro-optics, Non-linear Optics, X-ray absorption, Semiconductor Materials and Devices, Magnetism, Chaos, Lasers, Fiber Optics, Holography, Microsensors. In addition, we are very successful in placing our students in summer internship positions with various research facilities such as NASA, Argonne National Laboratory, Sandia National Laboratory, National Radio Astronomy Observatory, and CSPAAR.

PHYSICS

Freshman Year

Fall Term				Credit
MA	111	Calculus I		5
PH	111	Physics I		4
CLSK	100	College and Life Skills		1
RH	131	Rhetoric and Composition		
		or		
HSS		Elective		4
EM	104	Graphical		2
		Communications		
				16

Winter Term

				Credit
PH	112	Physics II		4
MA	112	Calculus II		5
CHEM	105	Engineering Chemistry I		4
		Computing Elective*		2-4
				15 or 17

Sophomore Year

Fall Term				Credit
		Free Elective†		4
PH	235	Many Particle Physics		4
MA	221	Differential Equations I &		
		Matrix		4
PH	292	Physical Optics		4
				16

Winter Term

				Credit
PH	255	Fund. of Modern Physics		4
HSS		Elective		4
		Technical Elective		4
MA	222	Differential Equations &		
		Matrix II		4
				16

Spring Term

				Credit
--	--	--	--	--------

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

<i>Spring Term</i>				PH 314	Theoretical Mechanics I	4
				HSS	Elective	4
				MA 371	Linear Algebra I	4
					Math Elective†	4
				16		
PH	113	Physics III	4			
MA	113	Calculus III	5			
CHEM	107	Engineering Chemistry II	4			
HSS		Elective				
		or				
RH	131	Rhetoric and Composition	4			
17						
Junior Year				Senior Year		
<i>Fall Term</i>				<i>Fall Term</i>		
				<i>Credit</i>		
HSS		Elective	4	Math	Elective†	4
PH	316	Electric and Magnetic			Technical Elective†	4
		Fields	4	HSS	Elective	4
		Technical Elective†	4		Free Elective	4
PH	405	Semiconductor Materials		16		
		and Applications	4			
16				<i>Winter Term</i>		
				<i>Credit</i>		
<i>Winter Term</i>				PH 425	Advanced Physics Lab II	4
				HSS	Elective	4
PH	317	Electromagnetism	4		Technical Elective†	4
PH	401	Intro Quantum Mechanics	4		Free Elective†	4
HSS		Elective	4	16		
		Physics Elective†	4			
16				<i>Spring Term</i>		
				<i>Credit</i>		
<i>Spring Term</i>					Technical Elective†	4
				OE 450	Laser Sys & App	
PH	325	Advanced Physics Lab I	4		or	
HSS		Elective	4		Physics Elective	4
OE	450	Laser Sys & App			Free Elective	4
		or			Physics Elective†	4
		Physics Elective†	4	16		
PH	327	Thermodynamics &				
		Statistical Mechanics	4			
16				Total credits required: 192		

* Computing elective: 2 or 4 credit course on computing from the following course: AB 140, CHE 110, CSSE 120, and ME 123. CSSE 120 is required for physics majors who are planning to double major with CSSE, CPE, EE, MA, and ME

†Free, Math and technical electives are only suggestions and can change subject to offering. Electives must be approved by PHOE advisor.

SUMMARY OF GRADUATION REQUIREMENTS FOR PHYSICS MAJORS

1. All the courses listed above by the number.
2. The program must be approved by the advisor.
3. Twelve credits of physics courses, besides those listed by number. At least two of these credits must be directed research (PH290 or PH490) with at least one credit of PH490.
4. Twenty credits of technical electives of which at least eight must be in courses other than physics courses (cannot include ECE340).
5. Cross reference for the following courses:
ECE340 and ECE341 for PH316 and PH317
ES202 and ES204 for PH235
6. Sixteen credits of free electives (cannot include ECE340).
7. Thirty-six credits of humanities or social sciences courses. The distribution of these courses must meet

the requirements of the Department of Humanities and Social Sciences.

- 8. A technical elective is any RHIT course in chemistry, computer science, engineering, applied biology, mathematics, or physics.
- 9. A free elective is any course offered at RHIT.

Course by Subjects	Hours
Physics Course work	56
Physics Electives*	12
Chemistry and Mathematics Course work**	35
Mathematics Electives***	8
Humanities and Social Science (Standard requirement)	36
Technical Electives†	20
Free Electives††	16
Miscellaneous and OE450†††	9
Total	192

*Listed below are the PH elective courses, from which a physics major is required to take 12 hours.

Course	Course Title	Hours
EP 280	Introduction to Nano-engineering	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
OE 172	Optics and Technology	2
OE 280	Paraxial Optics	4
OE 360	Opto-mechanics and Optical Materials	4
OE 393	Fiber Optics and Applications	4
OE 480	Lens Design and Aberrations	4
OE 485	Electro-Optics and Applications	4
OE 495	Optical Metrology	4
PH 230	Intro to Astronomy and Astrophysics	4
PH 265	Fundamentals of Nuclear Physics	4
PH 270	Special Topics in Physics	Arranged
PH 290, 490	Directed Research	Arranged
PH 302	Biophysics	4
PH 310	Intro to Relativity	2
PH 322	Celestial Mechanics and Solar System Physics	4
PH 330	Material Failure	4
PH 402	Introduction to Atomic Physics	4
PH 404	Acoustics	4
EP 406	Semiconductor Devices and Fabrication	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 437	Introduction to Image Processing	4
PH 440	X-rays and Crystalline Materials	4
PH 460	Directed Study	(Arranged)
PH 470	Special Topics in Physics	(Arranged)
PH497,498,499	Senior Thesis+	(Arranged)

+Students wanting to pursue the Senior Thesis option must find a faculty advisor (from the Physics and Optical Engineering Faculty) by the Fall Term of their Senior Year. At that time, the thesis topic should be decided and the research plan developed. Students in the thesis option should enroll in Senior Thesis courses for each of the three terms of their Senior Year (the number of credits will be determined with the guidance of the faculty thesis advisor). Students working on a Senior Thesis will present their thesis near the end of the Spring Term of their Senior Year.

**Math and Chemistry Courses:

Course	Course Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5

MA 221	Diff. Eq. I	4
MA 222	Diff. Eq. II	4
MA 371	Linear Algebra	4
CHEM 105	Engineering Chemistry I	4
CHEM 107	Engineering Chemistry II	4
Total		35

***Listed below are the mathematics elective courses, of which a physics major must choose two, or have the consent of the advisor to take any other mathematics courses.

Course	Course Title	Hours
MA 336	Boundary Value Problems	4
MA 330	Vector Calculus	4
MA 367	Functions of a Complex Variable	4
MA 433	Numerical Analysis	4

†Twenty credits of technical electives are required for a physics major, of which at least eight must be in courses other than physics courses (cannot include ECE340).

††A physics major may take sixteen credit hours of free electives, which may include any of the electives mentioned above or any other course offered at RHIT.

†††Miscellaneous Courses

Course	Course Title	Hours
CLSK 100	College and Life Skills	1
EM 104	Graph Comm.	2
OE 450	Laser System and Applications	4
	Computing Elective	2
Total		9

Area Minor Programs

The course requirements and advisors for Area Minors in Physics, Astronomy, Solid State Physics/Materials Science, and Optical Engineering are listed below. Successful completion of an Area Minor is indicated on the student’s grade transcript. A student interested in pursuing an Area Minor should consult with the appropriate advisor.

Area Minor in Physics

Eligibility: Students in any major degree program except for Physics and Engineering Physics

Advisors: all Physics and Optical Engineering faculty members.

Required courses:

Course	Course Title	Hours
PH 314	Theoretical Mechanics I	4
PH 325	Advanced Laboratory I	4

Plus three of:

Course	Course Title	Hours
PH 292*	Physical Optics	4
PH 310	Introduction to Relativity	4
PH 315	Theoretical Mechanics II	4
PH 316**	Electric and Magnetic Fields	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Quantum Mechanics	4

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy

Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science

Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours
OE 360	Opto-mechanics and Optical Materials	4
PH 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering

Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Diteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
PH 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE

Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4
ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering

Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site:<http://www.rose-hulman.edu/Class/phoe>



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Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Software Engineering

Software engineering is the creation of software using a process similar to other engineering disciplines. It allows for software to be reliable and developed within time and cost estimates. The software engineering curriculum prepares students for a career in reliable, economical software development.

Programming is only one phase (construction) of software engineering. There are many other aspects of the software engineering process, such as requirements definition, architectural design, and quality assurance, which need to be applied in order to develop reliable software on time and within budget constraints. The software engineering curriculum provides students a solid background in both the theory and practice of all phases in the software engineering process, beginning with their first course of study in the Department of Computer Science and Software Engineering, and continuing to the end of the senior year.

Since software is a non-physical product developed and executed on computers, the software engineering curriculum has computer science as its primary engineering science. The computer science courses taken by software engineering majors include the study of algorithms, data structures, database concepts, computer architecture, programming languages and operating systems. Software engineering majors also complete important courses in other closely related fields, such as discrete mathematics, digital logic design, and engineering statistics.

Coverage of software engineering topics begins in a three-term introduction to software development during the freshman and sophomore years. This study continues with coverage of core software engineering areas in the junior year, including software requirements, software architecture, software design, software project management, software construction, software maintenance, software evolution, software quality assurance, and formal methods in software specification and design. All of these courses include individual and team projects relevant to that particular area of software engineering. These projects generally include both written and oral presentations, building upon a technical communication course which introduces the student to the skills necessary for this important aspect of being a software professional. Throughout the senior year, a capstone team project develops and delivers software for a “real-world” client, which is put on display locally at a public exposition.

Throughout society, software exists for a wide variety of application domain areas. Each student is required to take at least three courses in a particular application domain, so that RHIT software engineering graduates can more effectively apply the software engineering principles they learn to that domain area. Students can choose from a variety of domain areas, including engineering, scientific and commercial applications.

Courses in various computer science topics such as computer graphics, artificial intelligence, computer networks, computer vision, web-based information systems, and cryptography are among those available as advanced electives. In addition, free elective courses allow students to tailor their undergraduate education to their specific goals.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Laboratory machines are mostly Sun Ultra workstations. Software engineering majors have unlimited access to the department’s laboratories. Software engineering students are frequently employed by the computing center as user consultants and by the department as system managers and course assistants.

The student chapter of the Association for Computing Machinery provides seminars and other technical activities

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

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throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

Graduates from the software engineering program will be prepared for many types of careers in software development. In the early phases of their careers, we expect Rose-Hulman software engineering graduates to be able to:

- 1. Develop complex systems (including analysis, design, construction, maintenance, quality assurance and project management) using the appropriate theory, principles, tools and processes.
- 2. Use appropriate computer science and mathematics principles in the development of software systems.
- 3. Solve problems in a team environment through effective use of written and oral communication skills.
- 4. Have knowledge of current issues presently involved in effectively performing duties as a software practitioner in an ethical and professional manner for the benefit of society.
- 5. Practice the lifelong learning needed in order to keep current as new issues emerge.
- 6. Develop software in at least one application domain.

Software Engineering Program Outcomes

By the time students graduate with a software engineering degree from Rose-Hulman, they will have demonstrated:

- The ability to apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex software systems
- The ability to design and experiment with software prototypes
- The ability to select and use software metrics
- The ability to participate productively on software project teams involving students from both software engineering and other majors
- Effective communications skills through oral and written reports and software documentation evaluated by both peers and faculty
- The ability to elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- The ability to evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- The ability to explain the impact of globalization on computing and software engineering
- The ability to interact professionally with colleagues or clients located abroad and the ability to overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- The ability to apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- The ability to identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- The knowledge required to understand the need for and the ability to perform in lifelong learning
- The basic knowledge required in a software engineering application domain track

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

SOFTWARE ENGINEERING

Freshman Year

<i>Fall Term</i>	<i>Credit</i>
CSSE 120 Introduction to Software Development	4
MA 111 Calculus I	5
PH 111 Physics I	4
RH 131 Rhetoric & Composition	4
CLSK 100 College and Life Skills	1
<hr/>	

Sophomore Year

<i>Fall Term</i>	<i>Credit</i>
CHEM 105 Engineering Chemistry I	4
CSSE 232 Computer Architecture I	4
MA 221 Differential Equations and Matrix Algebra I	4
MA 275 Discrete & Combinatorial Algebra I	4
<hr/>	

			18				16
<i>Winter Term</i>				<i>Winter Term</i>			
			<i>Credit</i>				<i>Credit</i>
CSSE	220	Object-Oriented Software Development		CSSE	230	Data Structures and Algorithm Analysis	
MA	112	Calculus II	4	CSSE	333	Database Systems	4
PH	112	Physics II.	5	MA	375	Discrete & Combinatorial Algebra II	4
HSS		Elective	4			Domain track course..	4
			4				4
			<hr/>				<hr/>
			17				16
<i>Spring Term</i>				<i>Spring Term</i>			
			<i>Credit</i>				<i>Credit</i>
ECE	130	Introduction to Logic Design		CSSE	304	Programming Lang.	4
MA	113	Calculus III	4	CSSE	376	Con Software Quality Assurance	4
HSS		Elective	5	MA			4
Science		Elective	4	RH	330	Elective	
			4			Technical and Professional Communication	4
			<hr/>				<hr/>
			17				16
Junior Year				Senior Year			
<i>Fall Term</i>				<i>Fall Term</i>			
			<i>Credit</i>				<i>Credit</i>
CSSE	371	Software Requirements & Specification		CSSE	377	Software Architecture and Design II	
CSSE	372	Software Project Management	4	CSSE	497	Senior Project I	4
MA	381	Introduction to Probability with Statistical Applications	4	HSS		Elective	4
		Domain track course	4			Domain track course or free elective	4
			4				4
			<hr/>				<hr/>
			16				16
<i>Winter Term</i>				<i>Winter Term</i>			
			<i>Credit</i>				<i>Credit</i>
CSSE	332	Operating Systems	4	CSSE	498	Senior Project II	4
CSSE	374	Software Arch and Des	4	CSSE		Elective	4
HSS		Elective	4	HSS		Elective	4
		Domain track course	4	Free		Elective	4
			<hr/>				<hr/>
			16				16
<i>Spring Term</i>				<i>Spring Term</i>			
			<i>Credit</i>				<i>Credit</i>
CSSE	373	Formal Methods in Specification and Design		CSSE	499	Senior Project III	4
				HSS		Elective	4
				Free		Elective	4

CSSE 375	Software Construction	4	
	and Evolution		12
HSS	Elective	4	
	Domain track course	4	
	or free elective	4	
			Total credits required: 192
		<hr/> 16	

Summary of graduation requirements for the software engineering major

To complete the major in software engineering a student must complete the following:

1. All required courses listed by number in the schedule of courses above: CSSE120, CSSE220, CSSE230, CSSE232, CSSE304, CSSE332, CSSE333, CSSE371, CSSE372, CSSE373, CSSE374, CSSE375, CSSE376, CSSE377, CSSE497, CSSE498, CSSE499; MA111, MA112, MA113, MA221, MA275, MA375, MA381; ECE 130; PH111, PH112, CHEM105; RH 131, RH330; CLSK100.
2. One additional CSSE elective course except CSSE 325, CSSE 473, CSSE 474, and CSSE 479. In addition, use of CSSE 49x to satisfy the CSSE elective requires approval of the Director of Software Engineering or the CSSE department head.
3. All of the courses in one of the following application domain tracks:

Biochemistry (4-5 courses, 16-20 credit hours)

- CHEM 107 Engineering Chemistry II (4)
- CHEM 230 Intro. to Organic Chem. & Biochemistry (4) or
- CHEM 251-252 Organic Chemistry I-II (4 each)
- CHEM 330 Biochemistry (4 hours)
- CHEM 363 Quantum Chem. & Molecular Spectroscopy (4)

Biomedical (3 courses, 12 credit hours)

- BE 310 Analysis of Physiological Systems I (4)
- BE 320 Analysis of Physiological Systems II (4)
- BE 360 Biomaterials (4)

Commercial Applications (3 courses, 12 credit hours)

- SV 151 Principles of Economics (4)
- SV 350 Managerial Accounting (4)
- SV 351 Managerial Economics (4) or
- IA 350 Microeconomics (4) or
- IA 453 The Entrepreneur (4)

Economic Computing (4 courses, 16 credit hours)

- SV 151 Principles of Economics
- IA 350 Intermediate Microeconomics
- IA 351 Intermediate Macroeconomics
- Plus any additional economics course

Electrical Engineering (4 courses, 16 credit hours)

- ES 203 Electrical Systems (4)
- MA 222 Differential Equations II (4)
- ECE 200 Circuits and Systems (4)
- ECE 300 Signals and Systems (4)

Ethics and Law of Business (3 courses, 12 credit hours)

- IA 101 Introduction to Philosophy (4)
- EMGTxxx Business Law (4)
- SV 303 Business and Engineering Ethics (4)

Engineering Management (3 courses, 12 credit hours)

- SV 151 Principles of Economics (4)
- SV 356 Corporate Finance (4)
- EMGT 526 Technology Management and Forecasting (4)

Fundamentals of Engineering (6 courses, 22 credit hours)

- MA 222 Differential Equations II (4)
- ES 201 Conservation and Accounting (4)
- ES 202 Fluid and Thermal Systems (3)
- ES 203 Electrical Systems (4)
- ES 204 Mechanical Systems (3)
- ES 205 Analysis and Design of Engineering Systems (4)

Game Development Domain Track (6 courses, 24 credit hours)

- CSSE 351 – Computer Graphics (4)
- CSSE 451 – Advanced Computer Graphics (4)
- CSSE 490 or CSSE491 (Special Topics/Directed Studies) – Computer Game Design (4)
- MA 323 – Geometric Modeling (4)
- IA 334 – Creative Writing (4)
- SV 231 – Introduction to Short Fiction (4)

Genetics (4 courses, 16 credit hours)

- AB 110 Biology – Cell Structure and Function
- AB 210 Mendelian and Molecular Genetics
- AB 411 Genetic Engineering
- AB 431 Genomics and Proteomics

Geography (3 courses, 12 credit hours)

- SV 191 - Cultural Geography (4)
- GS 491 - Geography of Europe (4)
- GS 492 - Geography of Africa and Southwest Asia (4)

International and Diversity Issues (4 courses, 16 credit hours)

- IA 311 Issues in German Culture
- GS 384 Japanese Society
- EMGT 533 Intercultural Communication
- SV 373 Gender Issues
- and some type of international experience related to the domain track (requires CSSE department head approval)

International Business and Economics (4 courses, 16 credit hours)

- SV 151 Principles of Economics (4 hours)
- IA 351 Intermediate Macroeconomics (4 hours)
- GS 350, International Trade and Globalization
- GS 351 International Finance (4 hours)

Mechanical Robotics Domain Track (5 courses, 19 credit hours)

- ME430 Mechatronics
- ES201 Cons & Acct Princ
- ES204 Mechanical Systems
- ME303 Kinematics
- ME435 Robotics Engineering

Music Comprehension (4 courses, 14 credit hours)

- SV 244 Music History: Medieval, Renaissance, Baroque
- IA 246 Music Theory I
- MUS 113 Music Skills I (Indiana State University course)

MUS 150 Introduction to Musical Traditions I (Indiana State University course)

Physical Modeling (4 courses, 16 credit hours)

- MA 222 Differential Equations and Matrix Algebra II (4)
- MA 323 Geometric Modeling (4)
- MA 371 Linear Algebra (4)
- MA 433 Numerical Analysis (4)

Robotics Domain Track (5 courses, 20 credit hours)

- ME430 Mechatronics
- ES203 Electrical Systems
- ECE207 Electrical Engineering
- ECE320 Linear Control Systems and ECE497 Mobile Robotics
- Or
- CSSE413 Artificial Intelligence and ME435 Robotics Engineering

Scientific Computing (4 courses, 16 credit hours)

- MA 222 Differential Equations and Matrix Algebra II (4)
- MA 373 Applied Linear Algebra for Engineers (4)
- MA 433 Numerical Analysis (4)
- MA 439 Mathematical Methods of Image Processing (4)

Statistical Applications (3 courses, 12 credit hours)

- MA 223 Engineering Statistics I
- or
- MA 382 Introduction to Statistics with Probability
- MA 383 Engineering Statistics II
- MA 386 Statistical Programming

World Political Studies (3 courses, 12 credit hours, plus one additional requirement)

- GS 366 The European Union (4)
- GS 163 International Relations (4)
- GS 363 European Politics and Government (4)
- and some type of international experience related to the domain track. (requires CSSE Department Head approval)

World Security and Economics Domain Track (6 courses, 24 credit hours)

- GS 163 International Relations
- GS 361 Politics of the Global Economy
- SV 151 Principles of Economics
- CSSE 432 Computer Networks
- CSSE 442 Computer Security
- MA 479 Cryptography

The application domain track should be selected in consultation with the student's academic advisor, and filed with that advisor by the beginning of the junior year. Exceptions to application domain track requirements require department head approval.

4. Four additional credits of courses offered by the Department of Mathematics excluding MA351 – MA356. The student's academic advisor must approve the course used to satisfy this requirement. Where appropriate, a course in the student's application domain track can be used to satisfy this requirement.
5. Four credits of science electives, which can be any CHEM, PH, or AB courses not already required for the software engineering major.
6. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences; the distribution of these courses must meet the requirements of that department. Where appropriate, one or more courses in the student's application domain track can be used to satisfy part of this requirement.
7. Sufficient free elective courses to meet the minimum credit hour requirement of 192 hours for a software engineering major. These courses must have the approval of the student's academic advisor. Free electives may be selected from any Rose-Hulman course.

Area Minor in Software Engineering

Advisor: Dr. Shawn Bohner

Required Courses

- CSSE 120, Introduction to Software Development
- CSSE 220, Object-Oriented Software Development
- CSSE 230, Data Structures and Algorithm Analysis
- CSSE 371, Software Requirements and Specification
- CSSE 372, Software Project Management
- Two additional courses in software engineering chosen from CSSE 373-377.



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AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Programs of Study

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies

Air Force ROTC is designed as a four year training program that culminates in a student's becoming an Officer in the United States Air Force. This program is designed to run concurrently with the four year college curriculum and is open to all college students at no obligation.*

We also offer modified programs which can be completed in three or two years which also earn a commission in the Air Force. Once students have completed Air Force ROTC and college requirements they are off to serve at least the next four years in leadership positions throughout the Air Force.

*Based on individual situations, Air Force ROTC will ask for an obligation before more advanced training or monies are paid to a student. Until such time, the classes are free and at no obligation, contact Air Force ROTC for more details.

Scholarships

The Air Force is looking for the best and brightest students the country has to offer. To assist these students with their college education, a variety of scholarships are offered on a nationwide competitive basis. Scholarship winners attending Rose-Hulman can receive up to the full cost of tuition, plus payment of most school fees. Scholarships also pay for books along with a monthly tax-free stipend, during the school year. In addition, Rose-Hulman offers financial incentives to students bringing their ROTC scholarship to Rose-Hulman. For more information on Air Force scholarships, contact Rose-Hulman Admissions or Air Force ROTC Detachment 218 at Indiana State University, Technology Center Room 203, Terre Haute, IN 47809-2245. Phone (812) 237-2657.

The Air Force ROTC courses are designed to develop the leadership and management skills required to be an effective Air Force officer. Topics range from Air Force history to ethics and values. The curriculum is separated into four (4) major areas:

Profession of Arms - Designed specifically for the continued development of professional knowledge and skills unique to the Air Force profession. Subject areas include officership, military law, laws of armed conflict, military customs and courtesies, and the individual's role in supporting organizational and Air Force policies.

Communications Skills - Designed specifically to enhance professional development, which is integrated throughout the AFROTC curriculum. Emphasis is on a progressive study of the various communication skills required of Air Force junior officers. The curriculum is designed to provide both instruction and application of principles and concepts in written communications, staff communication instruments, oral communication, and the nature and art of effective listening.

Leadership Studies - Designed to examine aspects of military leadership and management functions as a part of the overall concept of leadership. An examination of leader variables and characteristics provides a lead-in to a protracted study of leadership theory. Leadership and management skills are developed and applied in Leadership Laboratory and cadet corps activities. Leadership training is emphasized at Field Training where team sports, military drill, and special leadership problems are mandatory.

Military Studies/International Security Studies - Designed to develop an understanding of the nature of conflict and how the United States military forces, particularly aerospace forces, are developed, organized, and employed. Subjects include the need for national security, the evolution and formulation of American defense policy and strategy, regional security issues, and joint doctrine.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs

General Military Courses

Freshman Year

	Credit
AS 101 Found. of the US Air Force I	1
AS 101LLeadership Laboratory	0
AS 102 Found. of the US Air Force II	1
AS 102LLeadership Laboratory	0
AS 103 Found. of the US Air Force III	1
AS 103LLeadership Laboratory	0

Sophomore Year

	Credit
AS 201 Evol. of Air & Space Power I	1
AS 201LLeadership Laboratory	0
AS 202 Evol. of Air & Space Power II	1
AS 202LLeadership Laboratory	0
AS 203 Evol. of Air & Space Power III	1
AS 203LLeadership Laboratory	0

Professional Officer Courses

Junior Year

	Credit
AS 301 Air Force Lead. & Manag.	3
AS 301LStudies I	0
AS 302 Leadership Laboratory	3
AS 302LAir Force Lead. & Manag.	0
AS 303 Studies II	3
AS 303LLeadership Laboratory	0
Air Force Lead. / Manag.	
Studies III	
Leadership Laboratory	


Senior Year

	Credit
AS 401 Nat.Sec.Aff./Prep. for Active	3
AS 401LDuty I	0
AS 402 Leadership Laboratory	3
AS 402LNat.Sec.Aff./Prep. for Active	0
AS 403 Duty II	3
AS 403LLeadership Laboratory	0
Nat.Sec.Aff./Prep.for Active	
DutyIII	
Leadership Laboratory	

Leadership Laboratory is part of the curriculum for all four years of study. This lab is designed to give students hands-on application of the skills taught in the classes. In addition, students practice the various customs and courtesies and leadership skills they will be use once they enter active duty.

Benefits

Air Force ROTC classes, text books, and uniforms are free to all fully-enrolled cadets. Once enrolled as a full member of the program, cadets are eligible to attend a variety of professional development programs during the summer months. Successful completion of the Air Force ROTC program results in a commission as a Second Lieutenant in the active duty US Air Force.

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Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Humanities and Social Sciences

AREAS OF STUDY

Global Studies

Society and Values

MAJORS

International Studies (second major only)

GERMAN TECHNICAL TRANSLATION CERTIFICATE

MINORS

Anthropology

Art

East Asian Studies

Economics

European Studies

Geography

German

History

Ideas and Arts

Modern Languages

Economics

Japanese

Language and Literature

Latin American Studies

Music

Political Science

Philosophy and Religion

Psychology

Spanish

PROFESSORS

Bremmer, Brophy, Carlson, Carvill, Casey, Christ, Clark, Dyer, Garcia, Gardner, Heeter, Hirotani, House, Kim, Kukral, Kuo, Letsinger, Livingston, Luegenbiehl, Martland, Mason, Michel, Minster, Schumacher, Smith, Taylor, Turner, Watt, and Williams.

MISSION STATEMENT

To enable our students to become creative, sophisticated thinkers, active citizens, and effective leaders in the global community, the department contributes to a broad liberal education, introducing students to a wide array of disciplines and traditions in the humanities and social sciences. In doing so, it provides learning experiences that, in addition to their intrinsic value, enrich a scientific and technical education.

EDUCATIONAL OBJECTIVES

Within the context of a liberal education, the department fosters in its students the desire and the ability to:

think critically,

forming cogent, informed opinions, defining and solving problems with an awareness that societal processes are complex and interactive;

communicate effectively

to diverse audiences, including those from other cultures and communities;

succeed in a global context

by understanding and adapting to diverse cultures, alternative points of view, and the challenges of globalization;

exhibit ethical and responsible leadership

as individuals, citizens, and professionals, committed to lifelong learning and achievement.

DISCIPLINES

The HUMANITIES study what it means to be human within a contemporary or historical context. These disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

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existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art	Anthropology
English and Literature	Economics
Foreign Languages (German, Japanese, and Spanish)	Geography
History	Political Science
Music	Psychology
Philosophy and Religion	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

Global Studies (GS prefix): Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

Ideas and Arts (IA prefix): Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

Society and Values (SV prefix): Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

In addition, courses related to communication skills and foreign languages have their own designations:

- Rhetoric and Composition (required of all students, with the exception noted below) and Technical Communications are designated with an RH prefix. Rhetoric and Composition is RH 131 and Technical Communications is RH 330
- Foreign language courses are identified by prefixes which identify the language: GE for German, JP for Japanese, and SP for Spanish

COURSE LEVELS IN THE HUMANITIES AND SOCIAL SCIENCES

The courses in the Humanities and Social Sciences Department are intended to contribute to our students' broad liberal education. Given this, they frequently do not follow a sequence or require prerequisites. This does not mean, however, that there is no distinction between upper and lower level courses. In general **lower level courses (100 and 200 level)** tend to be broad surveys of particular subject areas within disciplines. **Upper level courses (300 and 400 level)** are often more focused in terms of subject matter and may go into greater depth of content.

GRADUATION REQUIREMENTS

1. General

All students must take a minimum of nine courses (36 credits) in Humanities and Social Sciences (HSS). These courses may be chosen from the HSS offerings, within the restrictions below. (A student taking an area minor in HSS must take a minimum of ten to eleven courses; see below.)

2. Rhetoric and Composition

All students, with the exception noted below, are required to take RH 131, Rhetoric and Composition, on

campus. Freshmen, unless exempted or taking a foreign language, are normally enrolled automatically in the course in either the Fall or Winter Quarter. Students who have taken a writing course at another college will be granted IA transfer credit, but are not exempted from RH 131.

EXEMPTION: An entering student (freshman or transfer) who meets both of the following requirements may be exempt from the RH 131 requirement. The student will not, however, be awarded credit for RH 131. **Any HSS course may be substituted for RH 131 for exempted students.**

- a. A combined score of 1500 or above on the Writing and Critical Reading sections of the Scholastic Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.
- b. Has received grades of B or higher in all high school English courses.

3. Distribution Requirements

All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

4. Foreign Language

Students who elect to take a foreign language should note the following special requirements.

- a. HSS credit will not be awarded for an introductory-level language class (GE111, JP111, or SP111) until the student takes and passes the following course in the language sequence.
- b. Students who take 2-3 courses in a foreign language sequence may allocate those language courses in any of the three **thematic categories** as they choose, but may have no more than one language course in any category. In other words, the student must still take at least one course in each **thematic category** in a discipline other than foreign language and must also take RH 131. If a fourth foreign language course is counted toward the general HSS requirements, it will count as the one additional course noted under the Distribution Requirements.
- c. Students who take twelve courses (four years) in a single language are exempted from RH 131 and from both courses in Global Studies.
- d. Students may not earn foreign language credit in their native languages.

Note: Students planning to study abroad should be sure to have their program approved ahead of time by the head of the HSS Department and by the head of the Department in which they are majoring.

5. Minors

Students may elect a minor in most of the HSS Department's disciplines. In addition, several interdisciplinary minors are available. (See below.)

Help with Requirements

Students having questions concerning these requirements should consult their advisers or the head of the HSS Department. A check sheet summarizing HSS graduation requirements is available in the HSS Department Office.

Minor

A student may elect to take an Minor in Anthropology, East Asian Studies, Economics, European Studies, Geography, German, History, Japanese, Language and Literature, Latin American Studies Philosophy and Religion, Political Science, Psychology, or Spanish, by concentrating 5 to 7 HSS courses in that area. NOTE: All Minors require taking one additional HSS course, for a minimum of 40 HSS credits (44 in the case of foreign languages). See the specific requirements listed under each Minor. Successful completion of the Minor is indicated on the student's grade transcript. A student interested in pursuing a Minor should consult with the appropriate Minor Adviser, listed below, for aid in planning a course schedule. No courses counted toward fulfilling the requirements for one minor may be counted in fulfilling the requirements of another minor.

<i>Minor</i>	<i>Advisor</i>
Anthropology	Scott Clark
Art	Steve Letsinger
East Asian Studies	Huei-Ying Kuo
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter

Geography	Michael A. Kukral
History	Samuel Martland
Japanese	Maki Hirotani
Language and Literature	Caroline Carvill
Music	Gary Turner
Latin American Studies	Gustavo Garcia
Philosophy and Religion	Heinz Luegenbiehl
Political Science	Terrence Casey
Psychology	Patrick D. Brophy
Spanish	John Gardner

Courses Offered

Global Studies

Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.

GS 128 Introduction to East Asian History 4R-OL-4C

Examine the changing political-economic and cultural orders in the East Asian region (including China, Japan, and Korea) from imperial to modern era.

GS 161 Comparative Politics 4R-OL-4C

Examines the politics and government of numerous countries around the world. Explores the concepts and principles of comparative political analysis.

GS 163 International Relations 4R-OL-4C

Analyzes the structures, actors, and major problems of the international political system.

GS 191 Geography of Middle East 4R-OL-4C

Introduces the culture, landscape, and peoples of the Middle East and North Africa through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from Afghanistan to Mauritania and all points between.

GS 207 Asian Religions and Philosophy 4R-OL-4C

Focuses on the thought systems of India, China, and Japan. Discusses Hinduism, Buddhism, Confucianism, Taoism, and Shinto.

GS 221 Colonial Latin America 4R-OL-4C

Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C

Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History 4R-OL-4C

Explores the history and interaction of major world regions, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 237 Science Fiction 4R-OL-4C

Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. Emphasizes science fiction's humanistic usefulness in examining human values from an "extra-species, extra-terrestrial" perspective and in assessing the effects of technology on varieties of belief structures and social institutions.

GS 285 Humans and Culture 4R-OL-4C

Examines human adaptation and diversity; language and its use; the development and variety of economic, political, religious, family gender and expressive institutions.

GS 291 World Geography 4R-OL-4C

Explores the people and lands of the world through studies and concepts from human geography with emphasis on cultural landscape,, maps, and visual interpretation. Emphasis is placed on the culture regions of Africa, Europe, Asia, the Middle East, and the South Pacific.

GS 313 Contemporary Spain 4R-OL-4C

Introduces historical, political, and above all cultural issues in Spanish society, beginning with an overview of Spain prior to the twentieth century, but concentrating on the period from 1975 to the present. Special emphasis on the unique characteristics of Catalonia, Galicia and the Basque Country. Taught in English.

GS 324 Gender and Work in China 4R-OL-4C

Examine Chinese women's economic roles against the background of modern world history and China's transformation from 1600 to 2000.

GS 327 Modern China 4R-OL-4C

Examine the divergent responses to western challenges among the Chinese intellectuals, women, and urban bourgeoisie between the nineteenth to the first half of the twentieth centuries.

GS 334 Travel in World Literature 4R-OL-4C

Examines a wide variety of literature—including some in translation—and emphasizes works that comment on travel, tourism, and the effects of colonialism.

GS 335 The Global Novel in the Twentieth Century 4R-OL-4C

Explores novels, written in or translated into English, by non-American authors. Provides students with multiple perspectives on different global cultures.

GS 336 Literature of War 4R-OL-4C

Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C

Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C

Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 350 International Trade and Globalization 4R-OL-4C Pre: SV 151

Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Pre: SV 151

Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Pre: SV 151

Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C

Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 363 European Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of selected European political systems.

GS 366 The European Union 4R-OL-4C

Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Contemporary Japan (Field trip to Japan) 4R-OL-4C

Examine contemporary Japan through the lectures, reading, and discussions during the course. Explorer the culture through the field trip to Japan.

GS 379 Japanese Culture 4R-OL-4C

Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 384 Japanese Society 4R-OL-4C

Examines the context within which individual Japanese live and work in contemporary Japanese society. Considers the “traditional” roots of Japan, the impact of industrialization, and current trends. Emphasizes the change and continuity in Japanese life, including the family and marriage, rural and urban lifestyles, education, and the organization of management and labor.

GS 391 Contemporary Europe 4R-OL-4C

Surveys the changes and dynamics confronting Europe in the 20th Century. The dissolution of empires and communism to the expanding European Union will be examined with maps, theories and concepts from political geography. Ethics and values related to territoriality, place, and culture will be examined.

GS 412 Topics in German Culture II 4R-OL-4C

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GE412.

GS 422 Industrial Revolution in Global Context 4R-OL-4C

Examines the changes in production, distribution, and consumption commonly known as the Industrial Revolution of the 18th and 19th centuries. Explores technological, economic, social, and cultural aspects of these changes, both in industrialized countries and in other parts of the world.

GS 431 Literary London 4R-OL-4C

Considers literary depictions of London, a highly symbolic and frequently used setting in 19th, 20th, and 21st century British literature. Covers a broad range of literary texts set in the city, including works by major authors of this genre and a number of recent works by ethnic minority writers.

GS 432 Literature and Film of the Global Economy 4R-OL-4C

Focuses on contemporary fictional and non-fictional narratives that address economic interdependence between nation states. Employs an interdisciplinary approach to contextualize these narratives.

GS 442 Art History: Renaissance to Modern 4R-OL-4C

Explores the creation and uses of visual art by world civilizations from the Renaissance to the present. Studies the cultural evolution brought about by scientific and technological changes which culminate in the Modern and Post-Modern eras.

GS 462 Postcolonial Literature 4R-OL-4C

Examines works by postcolonial writers and theorists, and covers contemporary human rights and anti-colonial/anti-globalization movements.

GS 469 Contemporary British Fiction and Film 4R-OL-4C

Covers fiction and film produced in the British Isles during the last half of the 20th and the beginning of the 21st century, including works by both canonical and non-canonical authors. Includes readings about a number of pressing issues in contemporary Britain, and focuses on literary responses to race and class concerns.

GS 491 Geography of Europe 4R-OL-4C

Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C

Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

Ideas and Arts

Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R-OL-4C

Introduces the student to the methods and subject matter of philosophy through a selective consideration of fundamental philosophical problems such as the nature of reality, the existence of God, the criteria of knowing, and the basis of morality.

IA 142 Drawing 4R-OL-4C

Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C

Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C

Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C

Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C

Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C

Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C

Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C

Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Jane Austen and the Rhetoric of Fiction 4R-OL-4C

Provides a guide to reading, appreciating, and analyzing Jane Austen's major novels. Analyzes a variety of film adaptations, comparing them to the novels in their rhetorical effects.

IA 237 Introduction to Drama 4R-OL-4C

Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C

Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science 4R-OL-4C

Examines rhetorical and philosophical approaches to persuasion in scientific argument. Emphasizes popular science writing and the role played by science in shaping public opinion and policy.

IA 240 Introduction to Shakespeare 4R-OL-4C

Studies Shakespeare's histories, comedies, tragedies, and romances. Focuses on close textual reading of selected plays within the intellectual framework of his era.

IA 241 Introduction to Film Studies 4R-OL-4C

Covers the formal elements of film and provides a vocabulary for analyzing film. Introduces film theory and criticism.

IA 244 Design and Color 4R-OL-4C

Explores visual design and communication, creative problem solving, color theory and aesthetics. Students engage in problem-solving to create projects using a variety of materials.

IA 246 Music Theory I: Concepts 4R-OL-4C

Teaches basic techniques of music notation and analysis of melody, harmony, rhythm, form, and style. Includes a comprehensive Analysis Project.

IA 302 Philosophy of Religion 4R-OL-4C

Examines the basic philosophical problems found in religion. Deals specifically with the nature of religion, the nature and existence of God, religious language, and the religious life.

IA 311 Topics in German Culture I 4R-OL-4C

Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 330 Documentary Film 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C

Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C

Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C

Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C

Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C

Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C

Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C

Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 339 Rebellion in American Literature 4R-OL-4C

Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 346 Music Theory II: Applications 4R-OL-4C

Pre: IA246 or consent of instructor. Applies notational and analytical techniques to arranging/composing tasks, using music notation software.

IA 348 Music Performance 1R-OL-1R

Pre: Consent of Instructor. Applies music skills in performance groups for music minors. May be repeated up to 4 hours.

IA 350 Intermediate Microeconomics 4R-OL-4C Pre: SV 151

Analyzes optimal choice, and the conditions required for efficient exchange in market economies. Emphasizes rational choice theory as it applies to consumers and businesses, with complementary examination of uncertainty, anomalous features of actual market behavior.

IA 351 Intermediate Macroeconomics 4R-OL-4C Pre: SV 151

Studies the economy as a whole, including factors affecting economic growth, unemployment and inflation. Explains economic events and considers how policies affect economic performance.

IA 352 Game Theory 4R-OL-4C Pre: SV 151

Introduces techniques used to solve strategic games encountered in business and economics. Analyzes behavior of economic agents in various situations including single and repeated games with perfect and imperfect information.

IA 353 History of Economic Thought 4R-OL-4C Pre: SV 151

Surveys the history of economic thought and examines the literature of economics from rhetorical, historical, and methodological perspectives using original sources.

IA 388 Chinese Nationalism 4R-OL-4C

Examine issues and debates surrounding the discussion on Chinese nationalism.

IA 431 History of the American Novel 4R-OL-4C

Studies the novel in America from its early examples into the present. Emphasizes influential novels with historical and societal impact, placing more recent novels into historical context.

IA 436 Reinterpretations of Literary Themes 4R-OL-4C

Examines pieces of literature which rework the themes, characters and/or plots of other works to show how different authors from different times and cultures reinterpret earlier works in their own way.

IA 450 Mathematical Economics 4R-OL-4C Pre: SV 151

Illustrates the use of mathematics in economic analysis. Includes discussion of mathematical programming, decision theory, the applications of differential and integral calculus, differential and difference equations.

IA 453 The Entrepreneur 4R-OL-4C Pre: SV 151

Describes the role of the entrepreneur and in small and large businesses. Uses economic analysis to study entrepreneurship and prepare business plans. Includes an application to a simulated entrepreneurial effort by the students.

IA 471 Literature of Madness 4R-OL-4C

Analyzes the literary, biographical, and scientific relationships between artistic and manic-depressed temperaments. Examines how “great wits and madness” relate.

Society and Values

Courses whose primary focus is on the dynamics, patterns, and values of human interaction and social institutions.

SV 134 Popular Literature 4R-OL-4C

Analyzes texts written for mass consumption, such as detective novels, horror stories, fantasy fiction, and contemporary thrillers. Explores these literary genres’ conventions, traditions, and sociohistorical contexts.

SV 151 Principles of Economics 4R-OL-4C

Includes both microeconomics and macroeconomics. Analyzes market behavior. Considers production and pricing decisions under alternative industrial structures. Examines the determinants of economic growth, unemployment and inflation, including fiscal and monetary policy.

SV 166 American Politics and Government 4R-OL-4C

Examines the ideology, culture, political processes, institutions, and public policy of the American democratic system.

SV 171 Principles of Psychology 4R-OL-4C

Surveys learning, motivation, personality, intelligence, abnormal behavior, social behavior, perception, emotion, and psychobiology. Stresses objective analysis of behavior and provides a foundation for advanced courses.

SV 191 Cultural Geography 4R-OL-4C

Explores themes, topics, and concepts in cultural geography studies with examples from a diversity of world areas. Included are studies and examples from language, religion, settlement, ethnicity, agriculture, urbanization, population, and popular culture.

SV 201 Religion and Ecology 4R-OL-4C

Examines religious and cultural beliefs, texts, and practices relating to the natural world, focusing primarily on historical transvaluations of the concept of nature.

SV 222 Western Civilization to 1500 4R-OL-4C

Introduces the origins and growth of ideologies and institutions that have shaped Western Civilization from the first sedentary societies until the first contact between Europe and the Americas. Emphasizes the development of society, religion, the economy, government, science, and technology.

SV 223 Western Civilization since 1500 4R-OL-4C

Introduces the development of ideologies and institutions that have shaped Western Civilization from the beginning of European colonialism to the Cold War, globalization, and the present day. Emphasizes changes in society, religion, government, the economy, and the impact of science and technology on daily life.

SV 226 The West in the East 4R-OL-4C

Analyze how the changing images of the West in China reflect China’s changing status in the global economy.

SV 231 Introduction to Short Fiction 4R-OL-4C

Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C

Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C

Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C

Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C

Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV 244 Music History: Medieval, Renaissance, Baroque 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 245 Music History: Classical, Romantic, Modern 4R-OL-4C

Surveys the music periods through reading, listening, and a research project.

SV 272 Experimental Psychology 4R-OL-4C

Emphasizes experimental analysis of perception, motivation, learning, and personality. Programmed and independent experiments are performed. Laboratory periods are arranged.

SV 288 Introduction to Sociology 4R-OL-4C

Examine the social and historical construction of our personal identity based on race, class, and gender as well as how social and global inequality is associated with these categories.

SV 291 Medieval Europe 4R-OL-4C

Explores the settlement, state and nation building, trade, innovation, and peopling of Europe from the age of Vandals, Goths, and Vikings to the Renaissance. Emphasizes wars, revolts, power and society in transforming the map of Europe through studies of historical geography.

SV 303 Business and Engineering Ethics 4R-OL-4C

Examines the ethical issues faced by professional engineers in the global corporate context. Deals with such topics as codes of ethics, professional autonomy, employer authority, and whistle blowing.

SV 304 Bioethics 4R-OL-4C

Introduces students to basic issues in bioethics such as physician-patient relationships, the conduct of research, cross-cultural concerns, and codes of ethics.

SV 322 Disasters and Modern Society 4R-OL-4C

Examines how people at different times and places have tried to explain and prevent natural and technological disasters, and how those disasters have influenced the development of modern society. Explores how societies have thought about nature and technology, measured costs in lives and property, and perceived obligations between rich and poor.

SV 325 Cities in Latin American History 4R-OL-4C

Examines the evolution of cities and urban life in Latin America since before 1500. Specific topics vary but will include some of the following: technology, architecture, daily life, government, mass politics, and violence.

SV 326 Overseas Chinese 4R-OL-4C

Examine theories about trading diasporas, the construction of ethnic others in nationalist discourses as well as historiographies on Chinese overseas migration from early modern to contemporary period.

SV 328 Comparative Business History 4R-OL-4C

Explore how culture matters to business organizations and the notion of entrepreneurship.

SV 332 Masculinity and Work in Fiction and Film 4R-OL-4C

Examines representations of masculinity in the workplace in literature, film, and popular culture, as well as the

intersection of masculinity with topics such as technology, race, and class from U.S. industrialization to the present.

SV 334 Utopian Thought and Literature 4R-OL-4C

Studies varieties of utopian thought from a cross-cultural perspective.

SV 336 Contemporary American Fiction 4R-OL-4C

Analyzes the evolution of the American novel since 1945, with an emphasis on the historical context of late 20th-century American culture.

SV 337 20th-Century American Novel 4R-OL-4C

Examines the American novel with representatives of the major 20th century literary periods: realism, modernism, postmodernism. Examines the themes and issues addressed in different decades and from different perspectives.

SV 338 Latin American Fiction: The Boom and Beyond 4R-OL-4C

Studies writers associated with the "Boom" in Latin American fiction (the expanded popularity beginning in the 1960's), along with their literary predecessors and descendents. Examines the relationship between literature and cultural context.

SV 339 Literature and the Environment 4R-OL-4C

Considers the relationship between art and the natural world. Readings may include myths and poems, travel and adventure narratives, activist projects and manifestoes, and scientific and philosophical essays, drawn from a variety of cultural traditions.

SV 350 Managerial Accounting 4R-OL-4C Pre: SV 151

Covers accounting concepts and procedures for preparation of financial reporting. Emphasizes use of accounting as a tool for management control and decision making.

SV 351 Managerial Economics 4R-OL-4C Pre: SV 151

Applies economic analysis to the management of modern business enterprise. Emphasizes demand estimation, business forecasting, uncertainty, investment decisions, capital budgeting, and pricing strategies. In addition to SL 151, students should have some knowledge of business statistics.

SV 352 Money and Banking 4R-OL-4C Pre: SV 151

Examines the nature and functions of financial markets and institutions. Analyzes the determination of interest rates and the processing of information. Considers the relationship between the financial system and the macroeconomy.

SV 353 Industrial Organization 4R-OL-4C Pre: SV 151

Examines the influence of market structure and competition policy on business firms' decisions. Discusses modern theories of the firm, implications of market power, strategic interaction, merger and acquisition activity, antitrust policy and regulation.

SV 354 Environmental Economics 4R-OL-4C Pre: SV 151

Analyzes the consequences of pollution and discusses possible solutions to reduce pollution. Introduces analytical tools used in environmental planning. Performs benefit-cost analyses of regulations dealing with air, water, and solid waste pollution.

SV 355 Health Economics 4R-OL-4C Pre: SV 151

Analyzes demand and supply of health care and the roles of medical technology and health insurance. Studies the behavior of physicians, the use of paramedics, preventive care, and outpatient care. Examines the rising cost of health care and analyzes appropriate public policy responses.

SV 356 Corporate Finance 4R-OL-4C Pre: SV 151

Introduces managerial finance. Examines the valuation of assets, the cost of capital, capital structure, working capital management, planning and budgeting, and long-term financing.

SV 357 Labor Economics 4R-OL-4C Pre: SV 151

Analyzes labor markets with theoretical, empirical, and policy applications. Explains the determination of employment and wages. Studies compensating wage differentials, labor market discrimination, labor unions and theories of unemployment.

SV 369 British Politics and Government 4R-OL-4C

Examines the historical development, ideology, culture, political processes, institutions, and public policy of the political system of the United Kingdom.

SV 373 Gender Issues 4R-OL-4C

Examines male-female differences in behavior, personality, emotion, and cognition. Examines how men and women differ as they pursue the goals of life and the degree to which these differences are innate or learned.

SV 375 Personality Theories 4R-OL-4C

Presents an organized summary of major contemporary theories of personality. Compares and contrasts theories of human behavior. Analyzes the degree that behavior is purposive, unconscious, instinctive, learned, modifiable, and predictable.

SV 382 Anthropology of Religion 4R-OL-4C

Examines various concepts and practices pertaining to the supernatural, focusing primarily on indigenous religions around the world. Discusses the relationships of religious beliefs, values, and practices with social organization, economic behavior, subsistence systems, and technology

SV 385 Archaeology & Prehistory 4R-OL-4C

Examines the human past through the analysis of cultural artifacts: the course focuses on the methods and techniques of archaeology and the study of the major cultural and social transformations from foraging to agricultural and complex civilizations.

SV 386 Human Evolution 4R-OL-4C

Examines human origins and ongoing evolution: examines the evidence of the fossil record and genes, compares human behavior with other primates, considers physical basis for behaviors, and the extent and causes of human physical diversity..

SV 413 Contemporary Germany 4R-OL-4C

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Same as GE413.

SV 450 Econometrics 4R-OL-4C Pre: SV 151

Applies statistical methods to problems of economic analysis. Stresses the use of regression analysis in economic research and discusses the special problems encountered in empirical investigation of economic phenomena. In addition to SL 151, the student should have some knowledge of statistics.

SV 463 Seminar on America’s Future 4R-OL-4C

Examines the key political, economic, and security challenges facing the United States in a changing global environment.

Communication

RH 131 Rhetoric and Composition 4R-OL-4C

Emphasizes rhetorical analysis of texts and images, research methods, and the conventions of academic writing, including argumentation.

RH 330 Technical and Professional Communication 4R-OL-4C Pre: RH 131

Provides students with instruction and practice in analyzing contexts, audiences, and genres; crafting documents to meet the demands and constraints of professional situations; integrating all stages of the writing process; and collaborating effectively within and across teams.

Special Topics and Directed Study

GS, IA or SV 399 – Special Topics 4R-OL-4C Arranged

Examines a selected topic in one of the HSS disciplines in depth. A particular offering may require a prerequisite or consent of the instructor.

GS, IA or SV 499 – Directed Study 4R-OL-4C Arranged Pre: Consent of the Instructor and HSS Department Head

Allows for individual study of an HSS topic selected by the instructor and the student(s). A plan of study, regular meetings with the instructor, and a major term project are required.

XX 456 Seminar for Economics Majors 2R-OL-2C F

Reviews research methods employed in economics, surveys selected topics and methods in current economic research, directs student toward approval of a senior project proposal.*Prerequisite: Junior or Senior standing while pursuing a major or double major in economics, or permission of instructor. Required of all Economics majors and double majors.*

XX 457: Directed Study for Economics Senior Project 2R-OL-2C W, S Pre: XX 456

Directed study leading to completion of a senior project that demonstrates the ability to pursue independent intellectual inquiry. *Prerequisite: Junior or Senior standing while pursuing a major or double major in economics, or permission of instructor; successful completion of XX456. Required of all Economics majors and double majors.*

Modern Languages

(NOTE: Students may not earn foreign language credit in their native tongue)

GE 111/112/113 German Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary training in hearing, speaking, reading, and writing German. Uses reading exercises to show the relationship between language and culture. Required language laboratory.

JP 111/112/113 Japanese Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provide elementary training in speaking, listening, reading and writing Japanese. Three types of characters, Hiragana, Katakana, and Kanji will be introduced as well as fundamental linguistic forms and functions of modern Japanese.

SP 111/112/113 Spanish Language and Culture I/II/III 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides elementary and intermediate training in oral/aural skills, reading, and writing Spanish. Enhances grammar presentations by means of appropriate readings that show the relationship between language and culture.

GE 211/212/213 German Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Reviews German grammar, emphasizing its logical sub-structure. Stresses analysis of complex sentences of scholarly German. Introduces the student to selected topics dealing with life in Germany as contrasted with life in the U.S. Provides continued practice in reading and speaking. Required language laboratory.

JP 211/212/213 Japanese Language and Culture IV/V/VI 4R-OL-4C F/W/S Pre: Preceding course or placement by examination.

Provides further training in speaking, listening, reading and writing Japanese. More advanced aspects of modern Japanese such as honorific and humble forms, empathic expressions, casual speech, and male and female speech are examined.

SP 211/212 Spanish Language and Culture IV/V 4R-OL-4C F/W Pre: Preceding course or placement by examination

Stresses conversational skills and intensive first year grammar review. Intermediate reading and discussion of texts on contemporary issues and cultural topics from Latin America and Spain.

SP 213 Spanish for Engineers 4R-OL-4C S Pre: SP 212 or placement by examination

Stresses language skills useful for the engineering profession. Provides training in advanced reading, writing and conversation with emphasis on the use of language in a professional context.

GE 311 Issues in German Culture I 4R-OL-4C F Pre: GE 213

Examines a variety of historical and contemporary issues in German popular and high culture. Same as IA 311.

GE 312 Reading German Texts 4R-OL-4C W Pre: GE 311

Studies and practices effective reading of German texts. Analyzes and evaluates their contents in discussions and the writings of short German essays.

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Pre: GE 312

Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C Summer Pre: Preceding course

Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Pre: GE 313

Introduces scientific and technological vocabulary; continues working with complex grammatical structures;

applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W Pre: GE 411

Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany S Pre: GE 412

Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program) 4R-XL-4C

Summer Pre: Preceding course

Develops advanced language communications skills. Presents further cultural aspects of contemporary Japanese. Introduces reading and writing of scientific Japanese. [This course is offered as a summer program at Kanazawa Institute of Technology.]

FL 299 Summer Language Study Abroad

Maximum Credit per Summer: 12. May be repeated. Credit for approved summer foreign language study abroad. May count towards a departmental minor, with the exception of a foreign language minor. Prior approval by the HSS Department Head and evidence of satisfactory completion required

HSS Majors

International Studies Major (IS) (second major only)

In the 21st century, technical work occurs increasingly in an international and multi-lingual arena. The International Studies major provides Rose-Hulman students with the opportunity to complement their primary major with a second major that prepares them for an interdependent, multicultural, and transnational world. Courses in the major focus on economic, cultural, and social processes that take place among nations and world regions. Topics may include globalization, post-colonialism, communication, migration, and environmental change.

Learning Outcomes:

1. Recognition of cultural diversity requires the comparison and analysis of historical, cultural, political, social, or regional differences.
 1. Analyze a socio-cultural artifact, event, or system of a society different from your own.
 2. Compare socio-cultural artifacts or systems in two or more cultures/world regions/civilizations
 3. Carry out a project involving meaningful contact with students, colleagues, clients, or sponsors abroad.
2. Transnational and global awareness requires an understanding of the ideas, systems, processes, or trends that have created a globally interdependent world.
 1. Explain the global causes or effects of an action or decision by nation-states, corporations, groups of people, or other actors
 2. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
 1. Assemble and evaluate resources for research in international studies.
 2. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA245	<i>World Literatures</i>
GS163	<i>International Relations</i>
GS285	<i>Humans and Culture</i>
GS291	<i>World Geography</i>
SV151	<i>Principles of Economics</i>
SV220	<i>World History</i>

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

- a. *International Political Economy*: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose *at least* three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General list

IA353	<i>History of Economic Thought</i>
GS322	<i>Industrial Revolution in a Global Context</i>
GS350	<i>International Trade and Globalization</i>
GS351	<i>International Finance</i>
GS352	<i>Economic Growth and Development</i>
GS361	<i>Politics of the Global Economy</i>
SV328	<i>Comparative Business History</i>
SV354	<i>Environmental Economics</i>

Regional list

GS128	<i>Introduction to East Asia</i>
GS161	<i>Comparative Politics</i>
GS222	<i>Modern Latin America</i>
GS366	<i>European Union</i>
GS363	<i>European Politics and Government</i>
GS399	<i>Geography of the Middle East</i>
GS492	<i>Geography of Africa</i>

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

- b. *Comparative Cultures*: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322	<i>Industrial Revolution in Global Context</i>
GS333	<i>Travel in World Literature</i>
GS334	<i>Global Novel in the 20th Century</i>
GS432	<i>Literature of the Global Economy</i>
GS462	<i>Postcolonial Literature</i>
SV191	<i>Cultural Geography</i>
SV201	<i>Religion and Ecology</i>
SV226	<i>The West in the East</i>
SV382	<i>Anthropology of Religion</i>

Regional list (including but not limited to the following courses)

IA311	<i>Topics in German Culture I</i>
GS128	<i>Introduction to East Asia</i>
GS207	<i>Asian Religions and Philosophy</i>
GS222	<i>Modern Latin America</i>
GS313	<i>Contemporary Spain</i>
GS327	<i>Modern China</i>

GS335	Arabic Literature
GS379	Japanese Culture
GS391	Contemporary Europe
GS442	Art History: Renaissance to Modern
GS492	Geography of Africa

- c. *Individualized Major*: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 499 Capstone Project in International Studies (4 cred.)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS Minors

Minor in Anthropology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

- Five courses in Anthropology.
 - The following three courses are required:
 - GS 285 Humans & Culture
 - SV 385 Archaeology & Prehistory
 - SV 386 Human Evolution
- A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- Substitutions may be made with the approval of the Minor Advisor

Courses

- GS 384 Japanese Society
- SV 382 Anthropology of Religion
- XX 399 Special Topics
- XX 499 Directed Study

Minor in Art

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Area Minor in Art has the following requirements:

- Five Courses in Art:
 - The following three courses are required:
 - IA142 Drawing
 - IA148 Beginning Photography
 - SV242 Visual Arts in Civilization
- A minimum of 40 credits in HSS courses must be earned to obtain the minor.
- Substitutions may be made with the approval of the Minor Advisor

Courses

- GS 442 Art History: Renaissance to Modern
- IA 142 Drawing
- IA 148 Beginning Photography
- IA 244 Design and Color
- SV 242 Visual Arts in Civilization

Minor in East Asian Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in East Asian Studies has the following requirements:

1. Three courses (or proficiency) in Japanese Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS 128 Introduction to East Asian History
 - GS 207 Asian Religions and Philosophy
 - GS 324 Gender and Work in China
 - GS 327 Modern China
 - GS 384 Japanese Society
 - SV 226 The West in the East
 - SV 326 Overseas Chinese
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Economics

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Economics has the following requirements:

1. Five courses in Economics, distributed as follows:
 - a. Principles of Economics (SV 151);
 - b. Intermediate Microeconomics (IA 350) or Intermediate Macroeconomics (IA 351);
 - c. Three additional Economics courses chosen by the student and approved by an Economics Minor Advisor. These shall be selected to provide some depth in the student's understanding of economic analysis and its applications;
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser

Courses

- GS 350 International Trade and Globalization
- GS 351 International Finance
- GS 352 Economic Growth and Development
- IA 350 Intermediate Microeconomics
- IA 351 Intermediate Macroeconomics
- IA 352 Game Theory
- IA 353 History of Economic Thought
- IA 450 Mathematical Economics
- IA 453 The Entrepreneur
- SV 151 Principles of Economics
- SV 350 Managerial Accounting
- SV 351 Managerial Economics
- SV 352 Money and Banking
- SV 353 Industrial Organization
- SV 354 Environmental Economics
- SV 355 Health Economics
- SV 356 Corporate Finance
- SV 357 Labor Economics
- SV 450 Econometrics
- XX 399 Special Topics
- XX 499 Directed Study

Minor in European Studies

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS 313 Contemporary Spain
 - GS 337 Shakespeare's Europe
 - GS 363 European Politics and Government
 - GS 366 The European Union
 - GS 431 Literary London
 - GS 469 Contemporary British Fiction and Film
 - GS 491 Geography of Europe
 - IA 311 Topics in German Culture I
 - IA 337 European Romanticism
 - SV 222 Western Civilization to 1500
 - SV 223 Western Civilization from 1500 to the Present
 - SV 291 Medieval Europe
 - SV 413 Contemporary Germany
 - XX 399 Special Topics
 - XX 499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Geography

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Courses

- GS 191 Geography of Middle East
- GS 222 Modern Latin America
- GS 291 World Geography
- GS 327 Modern China
- GS 391 Contemporary Europe
- GS 491 Geography of Europe
- GS 492 Geography of Africa
- SV 191 Cultural Geography
- SV 291 Medieval Europe
- XX 399 Special Topics
- XX 499 Directed Study

Minor in History

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in History has the following requirements:

1. Five courses in History
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS 128 Introduction to East Asian History

- GS 221 Colonial Latin America
- GS 223 World History
- GS 222 Modern Latin America
- GS 324 Gender and Work in China
- GS 327 Modern China
- GS 422 Industrial Revolution in Global Context
- IA 388 Chinese Nationalism
- SV 222 Western Civilization to 1500
- SV 223 Western Civilization since 1500
- SV 226 The West in the East
- SV 322 Disasters and Modern Society since 1700
- SV 326 Overseas Chinese
- SV 328 Comparative Business History
- SV 329 Cities in Latin American History
- XX 399 Special Topics
- XX 499 Directed Readings

Minor in Language and Literature

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Language and Literature has the following requirements:

1. In addition to RH 131 and HS330, five courses in Language and Literature.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS 237 Science Fiction
- GS 334 Travel in World Literature
- GS 335 The Global Novel in the Twentieth Century
- GS 336 Literature of War
- GS 337 Shakespeare's Europe
- GS 338 Contemporary Arabic Literature in Translation
- GS 412 Topics in German Culture II
- GS 431 Literary London
- GS 432 Literature and Film of the Global Economy
- GS 462 Postcolonial Literature
- GS 469 Contemporary British Fiction and Film
- IA 230 Fundamentals of Public Speaking
- IA 231 Introduction to Poetry
- IA 232 African American Music in American Literature
- IA 234 Major American Writers
- IA 236 Jane Austen and the Rhetoric of Fiction
- IA 237 Introduction to Drama
- IA 238 African American Literature
- IA 239 Rhetoric of Science
- IA 240 Introduction to Shakespeare
- IA 241 Introduction to Film Studies
- IA 330 Documentary Film
- IA 331 American Modernism
- IA 333 Representations and Redefinitions of Reality
- IA 334 Creative Writing
- IA 335 Bible as Literature
- IA 336 Mystery & Horror Literature
- IA 337 European Romanticism
- IA 339 Rebellion in American Literature
- IA 431 History of the American Novel
- IA 436 Reinterpretations of Literary Themes
- SV 134 Popular Literature
- SV 231 Introduction to Short Fiction

- SV 232 Introduction to Non-Fiction
- SV 233 Survey of American Literature
- SV 332 Masculinity and Work in Fiction and Film
- SV 334 Utopian Thought and Literature
- SV 336 Contemporary American Fiction
- SV 337 20th century American Novel
- SV 339 Literature and the Environment
- SV 234 The American Dream
- XX 399 Special Topics
- XX 499 Directed Study

MINOR IN LATIN AMERICAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Latin American Studies has the following requirements:

1. Three courses (or proficiency) in Spanish Language. (Language courses may be allocated in any of the three thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
 - GS 221 Colonial Latin America
 - GS 222 Modern Latin America
 - GS 323 The Andean Countries of South America
 - GS 313 Contemporary Spain
 - IA 332 Don Quixote
 - SV 329 Cities in Latin American History
 - SV 338 Latin American Fiction: The Boom and Beyond
 - XX 399 Special Topics
 - XX 499 Directed Topics
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Minor in Modern Languages (German, Japanese, and Spanish)

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Modern Languages has the following requirements:

1. Six successive courses, or the equivalent, in German, Japanese or Spanish.
2. RH 131 and 3 HSS courses, one in each category.
3. This means a minimum of 44 credits in HSS courses must be earned.
4. Students may not earn foreign language credit in their native languages.

First Year Courses

GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses

GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses

GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses

GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413 Japanese Language and Culture X/XI/XII

XX 399 Special Topics

XX 499 Directed Study

Notes:

Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.

Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

Minor in Music

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:

1. A minimum of 40 credits must be earned to obtain the minor. 36 of these credits must be in HSS courses. The remaining four (4) credits may be in an approved course from outside the HSS Department.
2. The following four courses are required:
 - o SV244 Music History: Medieval, Renaissance, Baroque
 - o SV245 Music History: Classical, Romantic, Modern
 - o IA246 Music Theory I: Concepts
 - o IA346 Music Theory II: Applications
3. To fulfill the fifth course requirement for the Area Minor in Music, the candidate may choose ONE of the following options:
 - a. A course from outside the HSS Department, approved by the Minor Advisor, such as:
 - ECE481 Electronic Music Synthesis
 - PH404 Acoustics
 - PH460 Directed Study (music-related)
4. IA 499: Directed Study in Music. Pre-requisite: consent of the Minor Advisor.
5. IA 348: Music Performance. Pre-requisite: consent of the Minor Advisor.
6. Four (4) credits of Satisfactory participation in one or more of the formal Performing Groups (Concert Band, Jazz Ensemble, String Ensemble, and Chorus) are required. Performance credit may not be transferred from another college. One academic term of satisfactory participation earns one credit. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for “satisfactory participation” will be provided to the candidate by the Minor Advisor.

Minor in Philosophy and Religion

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy and Religion has the following requirements:

1. Five courses in Philosophy and Religion, one of which must be Introduction to Philosophy (IA 101).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS 207 Asian Religions and Philosophy
- IA 101 Introduction to Philosophy
- IA 302 Philosophy of Religion
- IA 335 Bible as Literature
- SV201 Religion and Ecology
- SV 303 Business and Engineering Ethics
- SV 304 Bioethics
- SV 382 Anthropology of Religion
- XX 399 Special Topics
- XX 499 Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.

Courses

- GS 161 Comparative Politics
- GS 163 International Relations
- GS 361 Politics of the Global Economy
- GS 366 The European Union
- 363 European Politics and Government
- SV 166 American Politics and Government
- SV 369 British Politics and Government
- SV 463 Seminar on America's Future
- XX 399 Special Topics
- XX 499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Five courses in Psychology, distributed as follows:
 - Principles of Psychology (SV 171).
 - Experimental Psychology (SV 272).
 - Three other Psychology courses.
2. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

Courses

- IA 471 Literature of Madness
- SV 171 Principles of Psychology
- SV 272 Experimental Psychology
- SV 375 Personality Theories
- SV 373 Gender Issues
- XX 399 Special Topics
- XX 499 Directed Study

German Technical Translator's Certificate Program

A student may earn, in addition to one of the regular degree programs in science or engineering, a certificate of proficiency in German technical translation. Successful completion of this non-degree program partially fulfills the graduation requirements in humanities and social sciences.

Certificate Requirements

A student must have a 3.0 in the first two years of German and in his/her major, as well as permission of the instructor, to enter the third year language courses. Exceptions may be made by the instructor in charge of the program.

- a. A student must complete all the technical courses required by one of the Institute's degree-granting programs.
- b. A student must successfully complete the third and fourth year courses of the German Studies program (GE 311/312/313 and GE 411/412/413).
- c. A student who successfully completes the four-year language program is exempted from RH 131 Rhetoric and Composition, and from both courses in Global Studies (GS). This generally means that the student will only need to take three HSS courses other than German, one additional course in any category.

Commentary

A student who qualifies through the Foreign Language Examination administered at Rose-Hulman during Freshman orientation week, will be permitted to enroll in the appropriate level of German as determined by the foreign language faculty. A student who successfully completes a quarter of more advanced language at Rose-Hulman with a grade of C or better will be granted 4 hours of Credit by Examination for each quarter of language by-passed. (Note: a minimum of two terms of college language must be completed in order to receive HSS graduation credit.)

- a. A student who is in the German Studies Program in Culture and Technology is not required to take RH 131, Rhetoric and Composition.
- b. In order to obtain the Translator's Certificate, some students in some curricula may have to take more than the minimum number of credits required for graduation.
- c. Due to scheduling requirements of some regular degree programs, a student may also have to carry an overload in some terms. This means that the student will have to maintain a better-than-average grade point average to meet the Institute requirements permitting an overload. See the Student Handbook for details.
- d. A student is strongly urged, but not required, to spend at least one summer studying in an approved program for foreigners in Germany. Some small grants may be available to help defray expenses.



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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Intranet | Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Military

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

Curriculum

The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances

Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from \$250-400 per month during the school year and approximately \$20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships

ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of \$900 per year and a tax-free stipend allowance from \$300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at <http://www.rose-hulman.edu/AROTC/>

Applied Biology

Biochemistry

Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Engineering

Computer Science

Economics

Electrical Engineering

Engineering Physics

Mathematics

Mechanical Engineering

Optical Engineering

Physics

Software Engineering

Additional Programs of Study

Aerospace Studies (Air Force ROTC)

Biochemistry & Molecular Biology (Second Major Only)

International Studies Major (IS) (Second Major Only)

Military

Pre-Professional Programs

Partnership Institutions

Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College, University of Southern Indiana (USI) and DePauw University may participate in the Rose-Hulman Military Science program.

BASIC COURSE

Freshman Year

			Credit
MSL	110	Leadership and Personal Development	1
MSL	120	Foundations in	1
MSL	130	Leadership.. Basic Leadership	1

Sophomore Year

			Credit
MSL	201	Innovative Tactical Leadership	2
MSL	202	Leadership in Changing Environments	2
MSL	203	Leadership in Changing Environments II	2

Summer

			Credit
MSL	206	ROTC Basic Camp	4

ADVANCED COURSE

Junior Year

			Credit
MSL	301	Adaptive Team Leaders	3
MSL	302	Leadership Under Fire	3
MSL	303	Leadership Under Fire II	3

Senior Year

			Credit
MSL	401	Developing Adaptive Leaders	3
MSL	402	Leadership in a Complex World	3
MSL	403	Leadership in a Complex World II	3

TOTAL CREDITS REQUIRED: 27

*All contracted cadets must attend Leadership Laboratories and Physical Training.



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ROSE-HULMAN

INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Programs of Study

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Pre-Professional Programs

Many graduates of Rose-Hulman choose to pursue professional or graduate studies after completion of their undergraduate studies. Engineering and science curricula provide excellent backgrounds for careers in business, law, and medicine. A student planning to enter a professional or graduate school should seek information as to the requirements for entrance into the institution of their choice and should arrange their undergraduate program accordingly. Advisors are available on the campus to advise and assist students interested in pursuing such studies after graduation.

Pre-business

Any of the prescribed curricula at Rose-Hulman are satisfactory for entrance into a professional school of business administration. Students interested in this area will find courses in economics, statistics, operations research, and computer sciences particularly helpful.

Pre-law

Law schools accept superior students from a wide variety of undergraduate backgrounds. The analytical training and problem-solving techniques inherent in engineering and science programs are particularly helpful to students interested in pursuing law careers. Law schools require that the Law School Admission Test (LSAT) be taken prior to consideration for admission. Contact the Pre-Law Adviser for more information.

Pre-medicine

Because of the increased importance of engineering and instrumentation technology in modern medicine, medical schools are very interested in attracting superior students with engineering and science backgrounds. The various curricula at Rose- Hulman, when supplemented with elective courses available, enable the student to meet all course requirements for admission to medical school.

Each medical school has its own specific minimum academic requirements but the generally include basic courses in general chemistry, physics, organic chemistry, and biology. Programs in chemistry and chemical engineering provide especially helpful backgrounds for this purpose, but many Rose-Hulman graduates from a variety of disciplines such as mathematics, physics, mechanical engineering, and electrical engineering, have completed medical school and are successful practicing physicians.

Application to a medical school should be made between May and October of the year previous to that in which the applicant expects to enter. The Medical College Admissions Test (MCAT) is required for consideration for admission. Interested students should contact the Health Professions Adviser for additional information.

- Applied Biology
- Biochemistry
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Economics
- Electrical Engineering
- Engineering Physics
- Mathematics
- Mechanical Engineering
- Optical Engineering
- Physics
- Software Engineering

Additional Programs of Study

- Aerospace Studies (Air Force ROTC)
- Biochemistry & Molecular Biology (Second Major Only)
- International Studies Major (IS) (Second Major Only)
- Military
- Pre-Professional Programs



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Information For

Prospective Students
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INSTITUTE OF TECHNOLOGY

Intranet | Contact

AboutAdmissionsAcademicsStudent LifeNewsCalendarsAlumniAthletics

Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Aerospace Studies (Air Force ROTC)

Course Descriptions - Aerospace Studies

LTC Schramm, MAJ Buchanan, CAPT Cordrey

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Pre: None
This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Pre: AS 101 or instructor permission
This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Pre: AS 102 or instructor permission
This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory F,W,S Pre: Enrollment in AS 101, AS 102, or AS 103
Meets one day a week for 2 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 201 The Evolution of Air and Space Power I 2R-3L-2C F Pre: AS 103 or instructor permission
This course designed to examine the general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values, through the use of operational examples and historical Air Force leaders, and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 202 The Evolution of Air and Space Power II 2R-3L-2C W Pre: AS 201 or instructor permission
This course is a continuation of the fall quarter course designed to examine the general aspects of air and space power through a historical perspective.

AS 203 The Evolution of Air and Space Power III 2R-3L-2C S Pre: AS 202 or instructor permission
This course is a continuation of the winter quarter course designed to examine the general aspects of air and

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

space power through a historical perspective.

AS 201L/AS 202L/AS203L Leadership Laboratory F,W,S Pre: Enrollment in AS 201, AS 202, or AS 203

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 301 Air Force Leadership Studies I 3R-3L-4C F Pre: Enrollment in Professional Officer Corps

This course is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

AS 302 Air Force Leadership Studies II 3R-3L-4C W Pre: AS 301

This course is a continuation of the fall quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 303 Air Force Leadership Studies III 3R-3L-4C S Pre: AS 302

This course is a continuation of the winter quarter course designed to study leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer.

AS 301L/AS 302L/AS303L Leadership Laboratory F,W,S Pre: Enrollment in AS 301, AS 302, or AS 303

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.

AS 401 National Security Affairs and Preparation for Active Duty I 3R-3L-4C F Pre: AS 303

This course examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

AS 402 National Security Affairs and Preparation for Active Duty II 3R-3L-4C W Pre: AS 401

This course is a continuation of the fall quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 403 National Security Affairs and Preparation for Active Duty III 3R-3L-4C S Pre: AS 402

This course is a continuation of the winter quarter course designed to examine the national security process, regional studies, advanced leadership ethics, and Air Force doctrine.

AS 401L/AS 402L/AS403L Leadership Laboratory F,W,S Pre: Enrollment in AS 401, AS 402, or AS 403

Meets one day a week for 3 hours. This class is mandatory for cadets who apply for membership in the AFROTC program and who are pursuing a commission in the United States Air Force. Cadets apply leadership concepts and principles, and practice critical skills needed to be an effective Air Force officer. Activities include physical fitness training, communication exercises, drill and ceremonies, and active duty Air Force experiences.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Applied Biology & Biomedical Engineering

Applied Biology and Biomedical Engineering Faculty: Ahmed, Anthony, Buckley, Coppinger, Dee, Ingram, Livesay, O'Connor, Rogge, Waite, Weiner, Xu

Applied Biology

AB 101 Essential Biology 4R-OL-4C F,W,S Pre: None

Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed AB110, AB120 or AB130 cannot receive credit for taking AB101.

AB 102 Nutrition4R-0L-4C W Pre: none

This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for AB or BE majors and not as an AB elective.

AB 110 Cell Structure and Function 3R-3L-4C F,S Pre: None

Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

AB 120 Comparative Anatomy & Physiology 3R-3L-4C W Pre: None

The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

AB 130 Evolution and Diversity 3R-3L-4C S Pre: None

Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

AB 191 Special Topics in Applied Biology XR-0L-XC Arranged Pre: Consent of instructor

Covers material of mutual interest to students and instructors which cannot be acquired in any other listed AB course.

AB 210 Mendelian and Molecular Genetics 3R-3L-4C F Pre: AB 110 or instructor consent

A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

AB 220 Prokaryotic Cell and Molecular Biology 3R-3L-4C W Pre: AB 110 or instructor consent

Discusses the essential properties of eubacteria and archea. Bacterial nutrition, growth, genetics and structural and metabolic diversity are discussed in detail. The basics of virology are also addressed. Fundamental laboratory methodologies are also covered.

AB 230 Eukaryotic Cell and Molecular Biology 3R-3L-4C S Pre: AB 110 or instructor consent

Examines the structure and function of various eukaryotic cells. Biomembranes, organelles, the cytoskeleton, energetics, protein sorting, signal transduction and cell interactions are discussed in detail. Essential methods in cell biology are addressed in both lectures and laboratories.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

AB 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111, or CHEM 105 or CHEM 201, or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with CHEM 264.

AB 301, 302 Biology Colloquium 1R-0L-1C F, W Pre: Junior standing

A discussion of selected timely topics and preparation for senior research.

AB 310 Plant Structure & Function 3R-3L-4C S Pre: AB 130 or instructor consent

Surveys the structure, physiology, diversity, evolution, and ecological importance of plants and related groups of organisms.

AB 320 Ecology 3R-3L-4C F Pre: AB 130 or instructor consent

Surveys adaptations of organisms, population dynamics, species interactions, and the structure and function of natural communities and ecosystems.

AB 330 Evolutionary Biology 4R-0L-4C W Pre: AB 130 or instructor consent

Surveys three major themes of evolutionary biology: adaptation, diversity of life, and the shared characteristics of life. Mechanisms of evolution, speciation, phylogeny, and macroevolutionary processes are discussed.

AB 340 Introduction to Biomedical Research: Clinical Methodology 1R-1L-1C Pre: AB120, and Jr/Sr standing or consent of instructor

Designed to introduce applied biology/bioengineering students to the basics of biomedical research using the clinical methodology typical of patient sample analysis. Students will learn to relate testing procedures with specific diseases and to use data obtained from laboratory testing to understand more about specific patient health problems.

AB 401 Biology Colloquium 2R-0L-2C W Pre: Senior standing

Oral presentations and discussion of selected timely topics.

AB 410 Infection and Immunity 4R-0L-4C Arranged Pre: AB 110 or consent of instructor

Discussion of various pathogens, how they cause disease, and how they elicit the innate and adaptive immune responses employed to combat them. Cellular and molecular mechanisms of immunity are addressed, as is the epidemiology of various human diseases.

AB 411 Genetic Engineering 4R-0L-4C Arranged Pre: AB 210 or consent of instructor

Discusses the basics of molecular biology and the genetic and molecular techniques used to engineer prokaryotic and eukaryotic cells, plants, and animals for the production of useful traits or compounds. The application of DNA technology to the diagnosis and treatment of disease is also addressed.

AB 421 Applied Microbiology 4R-0L-4C Arranged Pre: AB110 or consent of instructor

Discusses the fundamental biology of microprobes and the processes underlying their use in the production of chemicals, therapeutics and foods. The basics of microbial ecology and the environmental applications of microbial biotechnology are also discussed.

AB 431 Genomics and Proteomics 4R-0L-4C S Pre: AB210 or consent of instructor

Exploration of the methodologies used to generate systems-level sets of genetic and protein data, and the tools used to access and analyze the prodigious amounts of data emerging from such projects. The application of these technologies to investigate biological questions and model complex biological systems is also discussed.

AB 441 Virology 3R-3L-4C Pre: AB110, or consent of instructor

Virology focuses on the study of viruses as well as non-viral entities such as prions and viroids. In this course, students will learn about the structures, genomes, replication strategies, and pathogenic mechanisms of various viruses. Viruses causing diseases of medical and economic importance will be emphasized. In addition, the techniques used to study viruses and the uses of viruses in the treatment of disease will be addressed.

AB 451 Cancer Biology 4R-0L-4C Pre: AB210, or consent of instructor

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

AB 461 Evolutionary Medicine 4R-0L-4C Arranged Pre: AB130 and AB210, or instructor consent.

This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

AB 491 Special Topics in Applied Biology XR-0L-XC Arranged Pre: Consent of instructor

Covers upper level material of mutual interest to student and instructor which cannot be acquired in any other listed AB course.

AB 492 Directed Study in Applied Biology XR-XL-XC Arranged Pre: Consent of instructor

Covers applied biology material of mutual interest to the student and instructor which cannot be experienced in any other listed AB course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted. Prior approval of the ABBE department is required to use this course to fulfill AB elective credit requirements.

AB 499 Senior Thesis Research 0R-12L-4C F, W, S Pre: Senior standing

Laboratory research under the direction of a faculty mentor. Culminates in an oral research presentation and publication of a Senior Thesis.

Biomedical Engineering

BE 100 Problem Solving in the Biological Sciences and Engineering 3R-3L-4C WPre: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, structured programming, and an introduction to bioinformatics and Working Model.

BE201 Biomedical Measurements 3R-3L-4C Pre: BE100, ES203

Discuss the measurement principles for biomedical engineering. Topics include op-amp circuit analysis, frequency analysis, fundamentals of digital gates and flip-flops, different types of biomedical sensors (temperature, force, pressure, velocity, etc), and basics of PIC microcontrollers and embedded system.

BE 310 Analysis of Physiological Systems I: 3R-3L-4C FPre: AB120

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach.

BE 317 Design for Biomedical Manufacturing 1R-0L-1C W Pre: EM 104

This BE course is to be taken concurrently with ME317, Design for Manufacturing. This course presents manufacturing methods associated with biomedical products and situates Design for Manufacturing within the larger context of 'cradle to cradle' design processes. Current biomedical industry processes and issues are emphasized. Taking ME317 and BE317 simultaneously, and passing both courses, will fulfill the requirement for a 4-credit BE biomechanics or biomaterials concentration elective.

BE 320 Analysis of Physiological Systems II: 3R-3L-4C W Pre: BE310

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach.

BE 331 Biomechanics 3R-0L-3C C WPre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE351 and BE361

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 340 Biomedical Instrumentation and Signal Processing 3R-3L-4C F Pre: Pre: BE 201 and ES 203, or consent of instructor

Topics include Circuit analysis, frequency analysis, biomedical transducers, design of biomedical devices, and introduction to imaging techniques.

BE 350 Biocontrol Systems 4R-0L-4C W Pre: ES 205

Systems representation and analysis in the frequency and time domain. Topics include Laplace transforms, modeling of electrical and mechanical systems, stability, steady-state error analysis, root locus design, frequency response analysis, and applications in physiology and medicine.

BE351: Biomedical Engineering Lab 1R-3L-2C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331 and BE361

This course emphasizes the fundamental concepts in biomechanics and biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods. Non-majors interested in taking this course should see the instructor

BE352: Biomechanics Lab 0R-6L-2C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE331

This course emphasizes the fundamental concepts in biomechanics through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE353: Biomaterials Lab 0R-6L-2C Pre: ES 201, EM 204, and BE 201, or consent of instructor Co: BE361

This course emphasizes the fundamental concepts in biomaterials through hands-on experience with standard testing equipment. Laboratory projects will be assigned which will require the students to use basic instrumentation to determine and execute effective test methods.

BE 361 Biomaterials 3R-0L-3C W

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 390 Principles of Biomedical Engineering Design 1R-3L-2CS Pre: BE 201

In this course, junior BE majors are introduced to the engineering design methodology as utilized in biomedical engineering. Students will learn engineering design through completion of a team design project with realistic constraints. This course serves as the entry point for the four-quarter sequence in which students undertake and complete their capstone design project.

BE 410 Biomedical Engineering Design I 3R-3L-4C Pre: BE390

This course begins the year-long capstone design project and continues to investigate the process of design in biomedical engineering by having student teams initiate the design process for a relevant problem in biomedical engineering. This includes developing the design problem from a set of client needs, establishing specifications, planning the project, scheduling, efficient use of resources, examining ethics and safety in engineering design, and working within explicit (or implicit) constraints such as social, fiscal, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 420 Biomedical Engineering Design II 2R-6L-4C Pre: BE410

This course is a continuation of BE410 by having student teams implement their design plan. This will include development of a test plan, modifications to the design project as needed, and assessment of design performance relative to initial specifications. This course culminates in the submission of the final design document.

BE 430 Biomedical Engineering Design III 1R-3L-2C Pre: BE420

This course is a continuation of BE420 and introduces students to the skills necessary for professional practice in biomedical engineering including project management, review of critical design decisions, mentoring design teams, etc. The biomedical engineering design sequence culminates in the formal oral presentation of the capstone design report.

BE 435 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 222, and SR/GR standing

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications. Same as OE 435. Students taking BE435/OE435 may not receive credit for BE535/OE535.

BE 482 Bioengineering Statistics 4R-0L-4C Pre: MA 223 or MA 382 and consent of instructor (cross listed with MA 482)

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491Special Topics in Biomedical EngineeringXR-0L-XCArranged Pre: Consent of instructor

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE492 Directed Study in Biomedical Engineering XR-XL-XC Arranged Pre: Consent of instructor

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term, and a maximum of 8 credits of this course are permitted.

BE 510 Biomedical Signal and Image Processing, 3R-3L-4C W Pre: BE201, JR, SR or Graduate standing or consent of instructor

Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Human Physiology A 3R-3L-4C F Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of neural, muscular, endocrine, reproductive and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class.

BE 512 Human Physiology B 3R-3L-4C W Pre: Junior, Senior, Graduate standing or consent of instructor

An analysis of cardiovascular, pulmonary, immune and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512).

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor.

BE 525 Biomedical Fluid Mechanics 3R-3L-4C Pre: EM 301 or CHE 301 or ES202 or consent of instructor

Includes cardiovascular physiology, Poiseuille flow, pulsatile flow in rigid tubes, pulsatile flow in large arteries, blood flow in the microcirculation, flow and pressure measurement, prosthetic heart valves, prosthetic arteries, dimensional analysis and modeling.

BE 531 Biomechanics II 3R-3L-4C Pre: BE331 or consent of instructor

Covers statics, dynamics and deformable body mechanics of biological systems. Topics include joint anatomy, muscle physiology, biomechanics of distance running, physiological response to acceleration, mechanics of bone, joint biomechanics and selected topics from current literature. The course includes a lab covering the use of a motion analysis system and force platforms.

BE 534 Soft Tissue Mechanics3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides an introduction to the various approaches used in modelling soft tissues, with particular attention paid to those of the musculoskeletal system (e.g. ligament, tendon, cartilage).Particular emphasis will be placed on the theoretical and experimental consequences of the large deformation behavior of these tissues. This course will serve as a Biomechanics track elective.

BE 535/OE 535 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 222, and SR/GR standing

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications.For graduate credit, students must do additional project work on a topic selected by the instructor.Students taking BE535/OE535 may not receive credit for BE435/OE435.

BE 539 Multiscale Biomechanics 3R-3L-4C Pre: EM 203 or EM 204, and BE 331, or consent of instructor

This course provides a comprehensive exploration/overview of the multiple approaches available for the analysis of multiscale media, beginning from classical approaches in composite theory and moving on to various structure-function and homogenization models.Specific attention will be placed on the application of these ideas to heterogeneous and finite deformation biological tissues (e.g. bone, cartilage, ligament, vessels, etc.). This course will serve as a Biomechanics track elective.

BE 541Medical Imaging 4R-0L-4C Pre: JR/SR/GR standing and consent of instructor.

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including computed tomography, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles and instrumentation of imaging modalities.Clinical

applications of these technologies are also discussed.

BE 543 Neuroprosthetics 3R-3L-4C Pre:BE310 and BE201

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Pre: EM 203 or EM 204, and BE 331 or consent of instructor

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Pre: BE 331 or consent of instructor

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Pre: Junior, Senior, Graduate standing or consent of instructor

Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactions 4R-0L-4C Pre: BE 361, or consent of instructor

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic-level results.

BE 570 Introduction to Tissue Engineering 4R-0L-4C Pre: Junior, Senior, or Graduate standing or permission of instructor

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 Thesis Research F,W,S

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term. F,W,S

The following courses are offered at the Terre Haute Center for Medical Education and may be taken for Rose-Hulman credit. To enroll in these courses RHIT students need permission from the Chairman of the Department of Applied Biology and Biomedical Engineering. BE 623 and BE 624 are typically offered in fall semester and BE 621 and BE 625 are typically offered in spring semester.

BE 621 Microbiology and Immunology (6 cr.)

Lectures, conferences and laboratories covering the immune response as a chemical and cellular Surveillance system; the consequences of activation of the immune system; and viruses, bacteria, fungi and protozoan and metazoan parasites as organisms and as agents of human disease.

BE 623 Gross Anatomy (8 cr.)

An intensive study of the gross structure of the human body accomplished through maximum student participation in the dissection of the human cadaver. Lectures are interpretive and correlative. Audiovisual supplementation is provided.


BE 624 Biochemistry (6 cr.)

The chemistry and reactions of constituents of living matter, including the carbohydrates, lipids, proteins, nucleic acids, vitamins, coenzymes and minerals; the chemistry and regulation of the reactions and processes of whole organisms; endocrinology; enzymology; nutrition; intermediary metabolism; and biochemical mechanisms in

selected disease states.

BE 625 Physiology (8 cr.)

The course in human physiology covers, in lectures and laboratories, such topics as circulation, respiration, digestion, endocrinology, heat metabolism, renal physiology, muscle physiology, and neurophysiology.



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Offices and Services

Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Chemical Engineering

Professors Anklam, Artigue, Coronell, Hariri, McClellan, Nolte, Sauer, Serbezov, and VanSchoiack.

CHE 110 Programming and Computation for Chemical Engineers 2R-0L-2C S Pre: None
An introduction to problem solving and programming using spreadsheets and Visual Basic for Applications (VBA). Spreadsheet applications include graphical analysis, curve-fitting, parameter estimation, numerical differentiation and integration, solution of systems of algebraic (linear and nonlinear) equations and ordinary differential equations. VBA programming topics include structured and object-oriented programming concepts as well as applications involving the creation of customized worksheet functions.

CHE 200 Career Preparation I 0L-0C F Pre: sophomore standing in Chemical Engineering
Career choices in chemical engineering, internship, coop, chemical industry working environment. 2-5 contact hours per quarter.

CHE 201 Conservation Principles and Balances 4R-0L-4C F Pre: CHEM 113, MA 113 and PH 111
An introduction to engineering calculations, the use of common process variables, and conservation and accounting of extensive properties - mass, energy, charge, linear momentum - as a common framework for engineering analysis and modeling. Applications of conservation of mass and energy in analysis of chemical engineering processes will be addressed including recycle, bypass and multi-stream processes. There will be an introduction to equipment, flowcharts, techniques and methodologies used by practicing chemical engineers. The use of computer software, especially spreadsheets, will be integrated into the course.

CHE 202 Basic Chemical Process Calculations 4R-0L-4C W Pre: CHE 201
Applications of the principles of conservation of mass and energy to reactive, multiphase, and transient systems. The course continues to develop concepts from CHE 201 and provides a more extensive treatment of energy balances.

CHE 300 Career Preparation II 0L-0C F Pre: Junior standing in Chemical Engineering
Career choices; preparation of resume; preparation for summer positions; preparation for graduate programs. 2-5 contact hours per quarter.

CHE 301 Fluid Mechanics 4R-0L-4C F,S Pre: CHE 201
Physical properties, fluid statics, laminar and turbulent flow of real fluids, boundary layer concept, interaction between fluid flow and contacting surfaces. Use of energy balances in design of pipe networks and pumps. Emphasis is placed on general methods of analysis applicable to any fluid. Solution of problems by computer will be stressed.

CHE 303 Chemical Engineering Thermodynamics 4R-0L-4C F,S Pre: CHE 202, MA221
First and second laws of thermodynamics and their application including thermodynamic cycles, closed and open systems. Thermodynamic properties of pure components. Phase equilibria of pure components. Equations of state, state diagrams. Thermodynamic analysis of processes.

CHE 304 Multi-Component Thermodynamics 4R-0L-4C F, W Pre: CHE 303, MA222
Properties of mixtures. Phase equilibria for mixtures. Equations of state and activity coefficient models. Chemical reaction thermodynamics. Thermodynamic analysis of processes. Project based study of phase equilibria involving the use of a process simulator.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

CHE 310 Numerical Methods for Chemical Engineers 4R-0L-4C W Pre: CHE 110, MA222 or concurrent enrollment

The objective of this course is to learn the fundamentals of several important numerical methods and how to apply them to solve chemical engineering problems. This will include the study of algorithms to solve systems of algebraic and differential equations, to perform numerical integration, to apply linear and nonlinear regression techniques, and to perform stochastic Monte Carlo simulations. Matlab and Excel will be used as the programming and computing software.

CHE 314 Heat Transfer 4R-0L-4C F, W, Pre: CHE 202, CHE 301, MA221

Discussion of fundamental heat transfer processes: conduction, forced and free convection, boiling and condensation, and radiation heat transfer. Mathematical analysis and computation of heat transfer and temperature profiles in solids with simple geometry. Estimation of local and overall heat transfer coefficients. Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries.

CHE315 Materials Science and Engineering 4R-0L-4C F,S Pre: CHEM 113

Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 325 Mass Transfer 4R-0L-4C W, S Pre: CHE 202, CHE 314, CHE 304

Principles of diffusion. Study of gas-liquid operations including gas absorption and distillation in equilibrium stage tray columns as well as packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium and rates of heat and mass transfer.

CHE 385 Quality Methods 4R-0L-4C S Pre: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-chart, C-charts, U-charts, Individuals Charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as MA 385.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Pre: CHEM 360 and CHE 304

Homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions and reactors, temperature and pressure effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR Standing (See EP 410/510.)

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in CHE 405/505 must do project work on a topic selected by the instructor.

CHE 409 Professional Practice 1R-0L-1C F

Topics on professional practice, project management, contemporary and global issues in the profession are discussed by students, staff and outside speakers.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHE 314, MA223, RH330

Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Pre: CHE 325, CHE 411 or consent of instructor

Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Pre: CHE 412

Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Design I: Process Economics and Equipment Design 4R-0L-4C F Pre: CHEM 252, CHE 325, CHE 404 or concurrent registration

Introduction to the design process; simulation to assist in process creation & analysis; synthesis of separation trains; design of separation towers, heat exchangers, pumps, compressors, expanders and other process equipment; cost accounting & capital cost estimation, trade-offs between capital and operating costs; design of reactor-separator-recycle networks.

CHE 417 Design II: Process Synthesis and Analysis 4R-0L-4C W Pre: CHE 416, CHE 404

Annual costs, earnings & profitability; process creation, optimization of process flowsheets; molecular structure design; heat & power integration; mass integration; optimal design & scheduling of batch processes. The course includes an open-ended process improvement project.

CHE 418 Design III: Capstone Design Project 0R-6L-2C S Pre: CHE 417

Completion of an open-ended design project which will include written and oral communication of intermediate status and the final design specifications.

CHE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent (See EP 411/511.)

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, and physics. Students enrolled in CHE 419/519, must do project work on a topic selected by the instructor.

CHE 420 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discusses problems in the field of consulting engineering. Seminars presented by practicing consulting engineers.

CHE 440 Process Control 4R-0L-4C W Pre: CHE 202, MA222

The mathematics of process dynamics, control system design, Laplace transforms, feedback control theory, characteristics of control elements, stability criteria, and frequency response. The course at times uses a personalized system of instruction format.

CHE 441 Polymer Engineering 4R-0L-4C F Pre: CHE 404 or concurrent registration in CHE 404 or consent of instructor

Interrelation of polymer structure, properties and processing. Polymerization kinetics. Methods for molecular weight determination. Fabrication and processing of thermoplastic and thermosetting materials. Student projects.

CHE 450 Air Pollution 4R-0L-4C F or W Pre: Junior or Senior standing

An introduction to air pollution and its control with special emphasis on the engineering aspects. Discussions of meteorology, health effects, sources and types of pollution, industrial control technology. Student projects.

Cross-listed with CE561.

CHE 461 Unit Operations in Environmental Engineering 4R-0L-4C F or W Pre: EM 301 or CHE 301

Physical-chemical unit operations pertinent to wastewater treatment such as membrane separations, filtration, coagulation, flocculation, ion exchange, carbon adsorption. Applications for unit operations from the chemical process industries are also covered. Cross-listed with CE563.

CHE 470 Safety, Health, and Loss Prevention 4R-0L-4C S Pre: Junior or Senior standing

Fundamentals of chemical process safety including toxicology, industrial hygiene, toxic release and dispersion models, fires and explosions, HAZOP analysis. Design of equipment to prevent fires and explosions. Risk assessment, including event and fault trees.

CHE 490 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering.

CHE 499 Directed Research F, W, S Pre: Permission of instructor

A special project is assigned to or selected by the student. The publication of research is encouraged. Variable credit. May be repeated up to a maximum of eight credits.

Undergraduate-Graduate Courses

CHE 502 Transport Phenomena I 4R-0L-4C Pre: CHE 325 or consent of instructor

Solution of the equations of change for momentum, energy, and mass transport. Mathematical determination of velocity profiles and momentum flux for isothermal flows inside ducts and over objects in both steady and unsteady systems. Turbulent flow theories. Mathematical determination of temperature profiles and heat flux, and concentration profiles and mass flux, in solids and laminar flows including boundary layers. Theoretical

bases for friction factors, convective heat transfer, and convective mass transfer coefficients. Dimensional analysis.

CHE 503 Transport Phenomena II 4R-0L-4C

Energy Transport: multidimensional systems; macroscopic balances for nonisothermal systems. Mass Transport: fundamentals of ordinary diffusion, multicomponent diffusion, pressure and thermal diffusion, coupled heat and mass transfer, boundary layer analysis, turbulent transport, mass transfer coefficients, macroscopic balances.

CHE 504 Advanced Reactor Design 4R-0L-4C W Pre: CHE 404

Strategies for modeling the effects of real reactor systems, including non-ideal flow and multiple phases. Applications in catalysis, combustion, biotechnology, polymerization, and materials processing. Computer methods and software for reactor engineering.

CHE 505 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in EP510, ME516, ECE516, CHE505, BE516 must do project work on a topic selected by the instructor.

CHE 512 Petrochemical Processes 4R-0L-4C F or W Pre: CHE 325 or consent of instructor

Multicomponent separation of petroleum by flash vaporization and by distillation. Catalytic processes for production of light petroleum products from heavier derivatives. Production of petrochemicals such as ethylene, methanol, and ammonia from natural gas. Group projects on refinery and petrochemical processes. Material balances and economic evaluations. Application of computer design packages and spreadsheets.

CHE 513 Advanced Chemical Engineering Thermodynamics 4R-0L-4C Pre: CHE 304

Review of thermodynamic principles including fundamental equations and the laws of thermodynamics. Thermodynamics of mixtures, phase equilibria, and thermodynamic analysis of processes. Project based in-depth study of phase equilibria, equations of state, and activity coefficient models. Use of process simulator for phase equilibria calculations. Introduction to statistical thermodynamics.

CHE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Students enrolled in EP511, ME519, ECE519, CHE519, BE516 must do project work on a topic selected by the instructor.

CHE 521 Advanced Chemical Engineering Computation 4R-0L-4C

The application of advanced mathematics to chemical engineering problems. The topics include: the formulation of the partial differential equations of kinetics and heat, mass and momentum transfer problems; series solution techniques; transform solution techniques; vector formulation; numerical methods for systems of differential equations; optimization, including linear programming, combinatorial optimization, and stochastic optimization techniques.

CHE 540 Advanced Process Control 4R-0L-4C Pre: CHE 440 and consent of instructor

Control topics beyond those covered in CHE 440. Topics will be selected from among the following: optimization, nonlinear control, adaptive control, multivariable systems, process dynamics, digital systems, system design.

CHE 545 Introduction to Biochemical Engineering 4R-0L-4C Pre: AB110, CHEM330, CHE 404 or ES201, or consent of instructor

Survey course introducing biochemical terminology and processes. Enzyme kinetics, cellular genetics, biochemical transport phenomena, and design and operation of biochemical reactors. Emphasis on applying engineering principles to biochemical situations.

CHE 546 Bioseparations 4R-0L-4C, Pre: AB110, CHE 325 or ES201, or consent of instructor

An analysis of bioseparation processes. Filtration, centrifugation, adsorption, electrophoresis, and chromatography are the primary topics of the course. Applications are emphasized.

CHE 590 Special Topics in Chemical Engineering 4R-0L-4C F, W, S

Topics of current interest in chemical engineering. May be repeated.

CHE 597 Special Projects in Chemical Engineering F, W, S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A

comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CHE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CHE 598 Graduate Seminar 1R-0L-0C F, W, S

Selected topics in chemical engineering are discussed by graduate students, faculty, and guest speakers.

CHE 599 Thesis Research F, W, S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Professors Allison, Brandt, R. DeVasher, Erwin, Morris, Mottel, Mueller, Nicholson, Shearer, Tilstra, and Weatherman

Chemistry Home Page - <http://www.rose-hulman.edu/chem/>

CHEM 105 Engineering Chemistry I 3R-3L-4C F,W,S

Topics include stoichiometry, nomenclature, reactions in aqueous solution including balancing oxidation-reduction reactions, atomic structure and periodic properties. Chemical bonding including Lewis dot structures, molecular geometry, and molecular orbital theory are considered in relation to the properties of solids, liquids, solutions and gases. Chemical kinetics along with the Arrhenius equation and nuclear reactions is covered. Not available for students who have credit for CHEM113. (Formerly CHEM 201)

CHEM 107 Engineering Chemistry II 3R-3L-4C W,S Pre: CHEM 105 or CHEM 201

Heterogeneous and homogeneous equilibria for gas-phase, solution phase, and acid/base reactions are covered. Electrochemistry, thermochemistry, and thermodynamics are also covered. Not available for students who have credit for CHEM 113. (Formerly CHEM 202)

CHEM 111 General Chemistry I 3R-4L-4C F Pre: None

The chemistry of matter. A laboratory-driven course which covers states of matter, equilibrium, solutions, and ionic equilibria. Assumes a working knowledge of algebra.

CHEM 112 General Chemistry Honors 4R-3L-5C F Pre: Advanced placement

An accelerated course covering topics in CHEM 111 and CHEM 113. An additional 3 credits will be awarded students with a grade of B or better. Enrollment is limited to those students who complete the chemistry Advanced Placement Examination with a score of 4 or who qualify on the basis of a chemistry placement examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-4C W Pre: CHEM 111

The chemistry of energy. A laboratory and reading-driven course which covers simple thermodynamic considerations, electrochemistry, chemical kinetics, and nuclear chemistry.

CHEM 115 General Chemistry III 3R-3L-4C W, S Pre: CHEM 113 or CHEM 112, or CHEM 107 or CHEM 202

A treatment of atomic structure and theories as they apply to the periodic properties of the elements. Chemical bonding and molecular geometry are also studied. The laboratory provides descriptive chemistry and logic in designing separation schemes for qualitative analysis.

CHEM 225 Analytical Chemistry 3R-4L-4C F, S Pre: CHEM 115, or CHEM 107 or CHEM 202

This laboratory-driven course is an introduction to classical and modern quantitative analysis with emphasis on calculations, separations, and precise and accurate measurements. Theoretical and practical perspectives of chemical analysis are considered. Chemical instrumentation includes recording pH/mV meters, constant rate burets, colorimeters, spectrophotometers, high performance liquid chromatographs and gas-liquid chromatographs.

CHEM 230 Introduction to Organic Chemistry and Biochemistry 4R-0L-4C F Pre: CHEM 107 or CHEM 202, or CHEM 115

An introduction to the concepts of organic chemistry as they apply to biochemistry, including stereochemistry,

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

nomenclature, and aqueous organic chemical reactions. Covers essential organic chemistry, including nomenclature, functional groups, and basic reactions. Introduces the fundamental molecules of biochemistry, including amino acids, nucleotides, carbohydrates, and lipids. Students may not receive credit for both CHEM 230 and CHEM 251.

CHEM 251 Organic Chemistry I 3R-4L-4C F Pre: CHEM 115, or CHEM 107 or CHEM 202

An introduction to the classification of organic compounds, their structural features, including stereochemistry, and the methods used to determine structure, including IR and NMR spectroscopy; concepts related to reaction mechanisms and synthetic methods are introduced.

CHEM 252 Organic Chemistry II 3R-4L-4C W Pre: CHEM 251

Continuation of Organic Chemistry I with greater emphasis on reaction mechanisms and synthesis.

CHEM 253 Organic Chemistry III 3R-4L-4C S Pre: CHEM 252

Study of carbanions, classical and non-classical carbocations, polyfunctional compounds, heterocyclics, orbital symmetry and more advanced reaction mechanisms, molecular rearrangements and syntheses.

CHEM 264 Introduction to Environmental Science 4R-0L-4C W Pre: CHEM 111 or CHEM 105 or CHEM 201 or consent of instructor

This course will introduce students to the broad field of environmental science by examining the biological, chemical, and physical processes that regulate the earth's ecosystems and the effect that anthropogenic activity has in disrupting these components on the local and global scale. A final aspect of the course will discuss sustainable human utilization of natural resources. Cross-listed with AB264.

CHEM 270 Geology and the Engineer: An Introduction 4R-0L-4C S Pre: CHEM 111 or CHEM 105 or CHEM 201

Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's perspective. The study of minerals and rocks, investigation of geologic hazards and interpretation of topographic maps, geologic maps and aerial photographs will be applied on local field excursions.

CHEM 275 Special Topics in Chemistry (1-4)R-0L-(1-4)C Pre: Permission of instructor

Studies in topics of current chemical interest not addressed in other named courses.

CHEM 276 Directed Laboratory Study in Chemistry 0R-3L-1C F Pre: Consent of instructor

Laboratory studies designed to supplement the background of entering students with an exceptional high school background in chemistry. This course is recommended for students entering with an AP 5 score.

CHEM 290 Chemical Research 0R-(4-8)L-(1-2)C

Research under the direction of a member of the faculty selected by mutual agreement. Freshman and/or sophomore students may earn up to 2 credits and are required to submit a written report to the chemistry faculty.

CHEM 291 Introduction to Chemical Research 3R-3L-4C W Pre: CHEM 115 or CHEM 107

Students will be introduced to skills necessary for conducting chemical research. Students will gain proficiency in: (1) literature searching of primary, secondary, and tertiary sources emphasizing the use of online databases; (2) laboratory skills involving synthesis, characterization, analysis, and keeping a notebook; (3) safety practice including MSDS interpretation; and (4) ethical conduct in collecting and reporting data and results. Students will also discuss research projects with at least three faculty members.

CHEM 304 Glassblowing 1R-3L-1C S Pre: Chemistry majors only or consent of instructor

A laboratory course in the manufacture, use and repair of scientific glassware. Six types of seals are constructed; a student-designed project is required.

CHEM 326 Bioanalytical Chemistry 3R-4L-4-C F Pre: CHEM 225

Addresses instrumental methods of analysis applicable to biochemistry including instrument design, operating principles, theory and application. Topics include molecular spectroscopic techniques in the infrared, visible and ultraviolet regions, including luminescence and Raman spectroscopy. Separation techniques including liquid chromatography and capillary electrophoresis are also addressed.

CHEM 327 Advanced Analytical Chemistry 3R-4L-4C W Pre: CHEM 225

Addresses theory, operating principles, and application of instrumental methods for chemical analysis in the areas of atomic spectroscopy, x-ray techniques, gas chromatography and electroanalytical methods.

CHEM 330 Biochemistry I 4R-0L-4C F Pre: CHEM 252 or CHEM 230

Includes the structure and function of biological molecules, enzyme kinetics and mechanisms, and the reactions, strategy, and regulation of carbohydrate metabolism.

CHEM 331 Biochemistry II 4R-0L-4C W Pre: CHEM 330 and AB 210

Includes the reactions, strategy, and regulation of the major metabolic pathways in humans and of selected pathways in plants, and the storage, repair, and transmission of genetic information.

CHEM 360 Introduction to Physical Chemistry for Engineers 3.5R-2L-4C

W, S Pre: CHE 303, CHE 304, and CHEM115

Introduction to statistical thermodynamics, electrochemistry, chemical kinetics, surface chemistry and colloid science. The laboratory will meet for 4 hours alternate weeks and will investigate topics associated with chemical kinetics and surface phenomena.

CHEM 361 Physical Chemistry I 4R-2L-4C F Pre: CHEM 115 and MA 221

Covers the laws of thermodynamics, free energy, gases, phase equilibria and solutions. Emphasizes the applications of differential and integral calculus and includes an introduction to statistical thermodynamics and surface chemistry. The laboratory will meet for 4 hours on alternate weeks and will investigate topics associated with thermodynamics and phase equilibrium.

CHEM 362 Physical Chemistry II 3R-2L-4C W Pre: CHEM 361

Covers chemical equilibria, statistical mechanics, kinetics and electrochemistry. The laboratory will meet for 4 hours on alternate weeks.

CHEM 363 Quantum Chemistry & Molecular Spectroscopy 4R-0L-4C S Pre: CHEM 115, or CHEM 105 or CHEM 201, MA 221, PH 112

Covers elementary quantum mechanics with emphasis on applications in molecular structure.

CHEM 401 Chemical Communication I 1R-0L-1C F

Students will engage in both oral and written communication that will culminate in a professional seminar and formal research report at the completion of this course sequence. Students will compose the literature survey and experimental sections of their formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will also recognize elements of effective oral presentations by attending and evaluating seminar speakers in the chemistry department's seminar series.

CHEM 402 Chemical Communication II 1R-0L-1C W Pre: CHEM 401

Students will engage in both oral and written communication that will culminate in a professional seminar and formal research report at the completion of this course sequence. Students will construct the data, results, and analysis sections of their formal research reports consistent with the guidelines presented in The ACS Style Manual. Students will develop an outline for their professional seminar. Students will also be required to attend the chemistry department's seminar series.

CHEM 403 Chemical Communication III 1R-0L-1C S Pre: CHEM 402

Students will engage in both oral and written communication that will culminate in the delivery of a professional seminar and a written formal research report, consistent with the guidelines presented in The ACS Style Manual.

CHEM 428 Environmental Analysis Methods (2R-8L-4C) Pre: CHEM 225 or permission of instructor

Environmental Protection Agency (EPA) procedures, American Standard Testing of Methods (ASTM), or other standard methods will be surveyed and used to analyze authentic samples. Students will use modern analytical and computerized instruments and will make decisions about procedures and optimal experimental conditions and they will assess the reliability and validity of their data. Classroom presentations will be directly related to the laboratory experience.

CHEM429 / CHEM529 Environmental Analysis and Remediation Strategies (4R-0L-4C) Pre: junior or higher standing

Environmental Protection Agency (EPA) procedures, American Standard Testing of Methods (ASTM), and current methods proposed in the literature will be surveyed. Method development and decision making matrices will be emphasized. Sampling protocols, remediation strategies, such as phytoremediation and bioremediation, chemometrics, and analysis techniques, such as supercritical extraction, capillary electrophoresis, biochemical microchip sensors, chromatographic methods, etc., will be discussed. [Concurrent laboratory experience may involve CHEM.476.]

CHEM 430 Advanced Biochemistry 4R-0L-4C S Pre: CHEM 330

An in-depth exploration of selected topics from the current biochemistry scientific literature, including molecular mechanisms of infectious diseases and genetic disorders, methods for rational drug design, and relationships between structure and function for biological molecules.

CHEM 431 Biochemical Instrumentation 3R-4L-4C Pre: AB 210 and CHEM 330

This project-based course includes approaches for the analysis of biochemical experimental problems,

experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 433 Biochemistry Laboratory 0R-4L-1C S Coreq: CHEM 430

Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I 4R-0L-4C F Pre: CHEM 252 and CHEM 362 or CHEM 360

The chemistry of non-metals. This course consists of a systematic study of the properties and reactions of the elements and their compounds based upon modern theories of the chemical bond, as well as from the viewpoint of atomic structure and the periodic law.

CHEM 442 Inorganic Chemistry II 3R-4L-4C W Pre: CHEM 441

The chemistry of metals. Modern theories such as valence bond, molecular orbital, electrostatic and ligand field are used to explain the properties of complex ions. Synthesis and characterization of complexes are done in the lab.

CHEM 445 Organometallic Chemistry 4R-0L-4C S Pre: CHEM 252

A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 451 Organic Structure Determination 2R-8L-4C S Pre: CHEM 253 or permission of instructor

Chemical and spectroscopic identification of organic compounds. Study of nuclear magnetic resonance and mass spectrometry, infrared spectroscopy and other techniques applied to structure elucidation and stereochemistry.

CHEM 452 Synthetic Organic Chemistry 4R-0L-4C F or W Pre: CHEM 253

A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 454 Theoretical Organic Chemistry 4R-0L-4C W Pre: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor

Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 455 Natural Products 4R-0L-4C Pre: CHEM 253 or permission of instructor

A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 457 Synthetic Polymer Chemistry 4R-0L-4C Pre: CHEM 252

Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 461 Advanced Physical Chemistry 4R-0L-4C Pre: CHEM 363

Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 462 Physical Polymer Chemistry 4R-0L-4C Pre: CHEM 252

Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanical properties.

CHEM 465 Environmental Organic Chemistry 4R-0L-4C Pre: CHEM 251 or CE 564 or consent of instructor

This course will examine the processes that control the fate of organic contaminants in the environment. Course topics include applying chemical thermodynamics to understand environmental fate, aqueous solubilities, partitioning behavior into various environmental compartments, sorption behavior, and the mechanisms and kinetics of some important abiotic transformations.

CHEM 470 Special Topics in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: permission of instructor

Studies in advanced topics of current chemical interest not addressed in other named courses.

CHEM 476 Directed Laboratory Study in Chemistry 0R-4L-1C F, W, S Pre: To be taken concurrently with the appropriate elective not accompanied by an identified laboratory component.

Laboratory studies designed to supplement an area concentration in organic, inorganic, analytical, physical, or some other field of chemistry.

CHEM 477 Directed Study in Chemistry (1-4)R-0L-(1-4)C F, W, S Pre: Permission of instructor

Allows individual study in a topic not usually offered. A student may take 1 to 4 credits. A maximum of 4 credits is permitted.

CHEM 490 Chemical Research 0R-(4-12)L-(1-3)C Pre: CHEM291

Research under the direction of a member of the faculty selected by mutual agreement. Students may earn a maximum of 18 credits between CHEM 290 and CHEM 490. Students may register for 1 to 3 credits per quarter.



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Civil Engineering

Professors Aidoo, Hanson, McKinney, Niezgoda, Robinson, and Sutterer

CE 101 Engineering Surveying I 0R-6L2C S Pre: None

Covers basic principles and practices of surveying. Mensuration through the application of surveying techniques; theory of errors and their analysis; concepts of horizontal, vertical and angular measurement; basic surveying operations and computations; reading and interpretation of building and construction plans.

CE 110 Computer Applications and GIS 4R-0L-4C W Pre: None

An introduction to problem solving, structured programming, and spatial analysis using spreadsheets, databases, and geographical information systems (GIS). Students will develop algorithms useful to civil engineering computation and design using these tools. This will include the development of programmed spreadsheets functions using structured programming concepts. Students will perform various spatial analysis techniques using GIS software including the use, collection, creation, and analysis of spatial data.

CE 111 Geographical Information Systems 2R-0L-2C W Pre: None

The course covers introductory concepts of geographical information systems and related technologies. Topics covered will relate to the use, collection, creation, and analysis of spatial data in applying GIS and related technologies to civil engineering projects. Not open to students with credit for CE 110.

CE 201 Engineering Surveying II 0R-6L-2C F Pre: CE 101

Covers special applied topics of surveying. Horizontal and vertical control systems and datums for engineering surveys; traverse computations; location of man-made structures; development and use of topographic maps; reading and interpretation of building, highway and bridge plans, land surveys and state plane coordinate systems; construction and route surveying.

CE 210 Civil Engineering Computer Applications 2R-0L-2C S Pre: CE 110 or equivalent and EM 104

Covers use of application programs (e.g., AutoCAD, Excel, MathCAD, etc.) useful to engineering computation and design.

CE 303 Engineering Economy 4R-0L-4C W Pre: Senior class standing

Emphasizes time value of money and factors related thereto. Familiarizes students with concepts of annual cost, present worth, and minimum rate of return as tools for consideration of economic factors pertinent to the selection of alternate solutions to engineering problems.

CE 310 Civil Engineering Numerical Methods 2R-0L-2C S Pre: CE 210 or equivalent and MA 222

Covers numerical methods used in solution of engineering problems. Typical topics include root finding, numerical integration, numerical differentiation, curve fitting, and numerical solution of ordinary differential equations.

CE 320 Civil Engineering Materials 3R-3L-4C S

A study of the origin, nature, performance and selection criteria of various basic materials used in the practice of civil engineering. These include aggregates, portland cement, concrete, and bituminous materials. Emphasis will be placed on standard methods of testing and characterization as related to the mechanical behavior of materials.

CE 321 Structural Mechanics I 4R-0L-4C F Pre: EM 203

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Pre: EM 203 and EM 301

Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Pre: EM 301 or equivalent

Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE 400 Career Preparation Seminar 1R-0L-0C S Pre: CE 489

Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 410 Senior Project 0R-8L-4C On Demand Pre: Senior class standing

Gives the student the opportunity to work on a civil engineering design or research project of the student's own choice, but which has met the approval of the staff prior to the start of the quarter. Requires presentation of oral and written reports. Not a regular elective offering.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills.

CE 421 Structural Mechanics II 4R-0L-4C W Pre: CE 321

Matrix methods of structural analysis for two- and three- dimensional indeterminate structures. Force method, stiffness method, introduction to finite element analysis for civil engineers.

CE 424 Composite Material Mechanics 4R-0L-4C On Demand Pre: CE 321

Introduces various laminated composite materials such as reinforced plastics, laminated glass, plywood, laminated timber, and fiber-structural sandwich. Emphasis is on beam theory and plane stress analysis for such materials.

CE 430 Structural Design in Timber I 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of modern structures constructed of timber. Considers fasteners and their significance in design. Develops design criteria and their application to plane and three dimensional structures.

CE 431 Structural Design in Steel I 3R-0L-3C S Pre: CE 321

Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor Design specifications. Includes tension and compression members, beams, beam-columns and connections.

CE 432 Structural Design in Concrete I 3R-0L-3C W Pre: CE 321

Deals with the analysis and design of reinforced concrete beams, floor slabs, and columns using the Ultimate Strength Design procedure.

CE 433 Structural Design in Steel II 4R-0L-4C On Demand Pre: CE 431

Covers the analysis and design of the various elements of a steel structure within the framework of the total structure. Includes composite design, plate girders, and multi-story building frames.

CE 434 Structural Design in Concrete II 3R-3L-4C Pre: CE 432

Advanced topics in reinforced concrete analysis and design such as strut-and-tie modeling, and strengthening with fiber reinforced polymers.

CE 435 Bridge Engineering 4R-0L-4C On Demand Pre: CE 321

Deals with the various types of bridge structures, the materials of which they are constructed and the manner in which loads are transmitted to the foundation. Includes methods and procedures for the analysis and design of bridge structures. Considers standards and procedures for inspections and ratings of bridges and methods to increase the load capacity of existing bridges. Includes field inspections.

CE 436 Foundation Engineering 4R-0L-4C S Pre: CE 336, CE 432

Covers the application of soil mechanics principles to foundation problems. Includes design of building foundations and retaining walls, stability analysis of open cuts and slopes, dewatering methods, and a study of the influence of local geology.

CE 441 Construction Engineering 2R-0L-2C W Pre: Junior class standing or consent of instructor

Covers planning and scheduling techniques for construction engineering: Gantt charts, critical path method, precedence diagramming method, activity on arrow and PERT methods, resource allocation, and time-cost tradeoffs.

CE 442 Cost Engineering 4R-0L-4C F Pre: Senior class standing

An investigation of some of the cost accounting, cost management and estimating techniques which are used in the construction industry. Various types of estimates will be considered, as will their multiple applications for project management. Special attention will be given to the preparation of detailed estimates based on quantity take-offs and to analyses of production productivity.

CE 444 Pavement Design and Highway Construction 4R-0L-4C On Demand Pre: CE 320

Introduction to analysis and design of rigid and flexible pavement systems; subgrade, subbase, base and surfaces; specifications, material testing and construction methods for soil stabilization, flexible and rigid pavements; pavement evaluation, maintenance and reconstruction.

CE 445 Construction Methods and Equipment 4R-0L-4C F Pre: CE 201 and CE 336, Co: CE 442

A study of economics, fundamental concepts and functional applications of major categories of construction equipment. Operational characteristics, capability and applicability of equipment to heavy, highway and major building construction projects.

CE 450 Civil Engineering Codes & Regulations 4R-0L-4C F Pre: CE 431 & CE 432

Examination of typical codes and regulations in the civil engineering profession. Local, state, and national building codes; Americans with Disabilities Act (ADA); zoning regulations; etc. Will also look at environmentally safe and renewable building materials, energy efficient construction techniques, indoor air quality and moisture problems, etc. Includes major building code evaluation and site development exercises.

CE 460 Introduction to Environmental Engineering 4R-0L-4C S Pre: EM 301 or CHE 301 or ES 202

Introduction to water pollution control, air pollution control, and solid and hazardous waste management. Topics include water treatment, wastewater treatment, impacts of pollutants on lakes and streams, and stream and air quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Co: CE 460

Emphasizes laboratory methods and interpretation of laboratory results for chemical analysis of water and wastewater.

CE 471 Water Resources Engineering 4R-0L-4C W Pre: EM 301 or CHE 301 or ES 202

Presents an overview of the engineering, planning, design, and operation of various water resources projects. Topics include surface and groundwater hydrology, sanitary and storm sewer design, dams and reservoirs, water law, wetlands, and nonpoint source pollution.

CE 480 Transportation Planning 4R-0L-4C On Demand Pre: Junior class standing

Analyzes the transportation planning process. Stresses goals and approaches to solutions as related to the urban transportation problem. Includes a class project.

CE 481 Transportation Engineering 4R-0L-4C W Pre: Senior class standing

Study of transportation functions and transportation systems including land, air and marine modes; transportation system elements including travel way, vehicle, controls and terminals; emphasis on highway geometric design.

CE 482 Urban Planning 4R-0L-4C On Demand Pre: Junior class standing

Applies general principles of systems analysis and control to urban and regional planning. Covers human settlements, location theory, simulation, plan formulation, selection and implementation. Includes a class project.

CE 489 Civil Engineering Design & Synthesis 5R-9L-8C F,W,S (1 R-3L-2C, fall; 3R-3L- 4C, winter; and 1R-3L-2C spring) Pre: RH 330, CE 460 Co-Req: CE 450

Civil engineering projects submitted by corporate and governmental sponsors will be undertaken by small teams of students to implement principles used in planning, design, and synthesis. Final recommendations and engineering designs will be presented to the sponsors with due attention to the social, economic, and environmental constraints of the project. The course is offered through the fall, winter, and spring at a rate of two credits per term for the fall and spring and four credits for the winter. No credit will be granted for the fall and/or winter terms alone. Eight credits will be granted after completion of the entire course in the spring term.

CE 490 Directed Studies F,W,S 1-4 C Arranged. Pre: Approval of department head, adviser, and course instructor

Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

Undergraduate-Graduate Courses

CE 520 Plates and Shells 4R-0L-4C On Demand Pre: CE 421 and MA 222

Development of classical plate equation and boundary conditions; solution of problems in rectangular and polar coordinates. Development of membrane and bending theories for shells of revolutions; solution to domes and storage tanks.

CE 522 Advanced Finite Element Analysis 4R-0L-4C On Demand Pre: CE 421

Development of finite element methods for solving plane strain, plane stress and field problems. Utilizes readily available finite element computer programs. Requires additional development of user computer programs.

CE 523 Structural Dynamics 4R-0L-4C On Demand Pre: CE 321

Presents the analysis and design of structures subjected to dynamic loads. Covers elastic and inelastic responses with applications to earthquake design, blast-resistant structures and bridge vibration.

CE 525 Buckling Strength of Structures 4R-0L-4C On Demand Pre: CE 321

Discusses the buckling phenomenon of prismatic bars subjected to combined axial and transverse loads. Considers elastic and inelastic instability. Includes buckling of beams, columns, curved bars, rings, plates, trusses and rigid frames.

CE 530 Structural Design in Timber II 4R-0L-4C On Demand Pre: CE 430

Presents the analysis and design of structures constructed of timber. Tapered beams, curved beams, box beams, stressed-skin panels, tapered columns, built-up columns, laminated arches, plate connected trusses, pole structures, diaphragms, shearwalls.

CE 531 Structural Design in Masonry 4R-0L-4C S Pre: CE 432

Presents the analysis and design of structures constructed of masonry. Material properties, beam design, unreinforced and reinforced walls, columns and pilasters, seismic provisions, diaphragms, shear-walls, connections, other masonry units - stone, marble, etc.

CE 533 Behavior of Metal Structures 4R-0L-4C On Demand Pre: CE 433

Discusses the behavior of metal connectors, members and structures. Studies the significance of this behavior in terms of design and the development of specifications. This course is closed to students who have successfully completed CE 433 Structural Design in Steel II.

CE 534 Behavior of Concrete Structures 4R-0L-4C On Demand Pre: CE 432

Studies the behavior of beams, slabs, and columns of reinforced concrete, prestressed concrete and composite construction from the standpoint of design and the development of specifications.

CE 535 Structural Design in Prestressed Concrete 4R-0L-4C On Demand Pre: CE 432

Analysis and design of prestressed concrete structures. Beams, slabs, loss of prestress, deflections, precast construction.

CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Pre: CE 436

Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 561 Air Pollution 4R-0L-4C W Pre: Grad or consent of Instructor

Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Treatability Studies 2R-6L-4C On Demand Pre: CE 563 or CHE 461

Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 563 Unit Operations in Environmental Engineering 4R-0L-4C F Pre: CE 460

Covers the physical, chemical, and biological operations and processes of interest to water and wastewater treatment systems. Topics include sedimentation, mixing, activated sludge coagulation, flocculation, granular filtration and adsorption. Cross-listed with CHE461.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Pre: Senior or Graduate student standing

Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The

carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Pre: CE 460

Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Pre: Graduate student standing

Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Pre: CE 471

Environmental planning and management strategies are examined using computer simulation models. Students will be introduced to some of the most widely used models in the fields of hydrology, hydraulics, and stormwater quality (nonpoint source pollution).

CE 568 Applied Contaminant Transport Modeling 4R-0L-4C On Demand Pre: CE 460 or consent of instructor

Environmental planning and management strategies are examined using computer simulation models. Emphasis is on pollutant transport in various media and emerging pollution issues. Students are introduced to some of the most widely used models in the field of environmental engineering. Students also develop at least one pollutant transport model using common software such as EXCEL, MATHCAD.

CE 569 Environmental Systems Optimization 4R-0L-4C Pre: Senior or Graduate class standing

Application of the principles of operations research to constrained optimization of environmental systems. Typical topics include strategies for non-linear searches, linear programming, dynamic programming, etc.

CE 570 Fluid Mechanics in Water Resources Engineering 4R-0L-4C On Demand Pre: CE 371

Presents steady and unsteady flow problems in open channels and pipes, problems dealing with laminar and turbulent boundary layers, and problems including diffusion and dispersion. There will be occasional laboratory work to demonstrate physical modeling in water resources engineering.

CE 573 Groundwater Analysis 4R-0L-4C Pre: CE 471

Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Pre: Graduate Standing F,W,S,F

Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication in a peer-reviewed professional journal. The final report to the sponsor and the manuscript prepared by the team must be approved by the team's graduate committee comprised of at a minimum, the course instructor, a faculty mentor from the CE department, and a faculty external to the CE department.

CE 590 Special Problems 2/4R-0L-2/4C F,W or S Pre: Consent of instructor

Special problems or reading by special arrangement with the faculty.

CE 597 Special Projects in Civil Engineering F,W,S Pre: Permission of instructor

A special project, or series of problems, or research problem is assigned to or selected by the student. A comprehensive report must be submitted at the conclusion of the project. Not to be used as a substitute for CE 599, Thesis Research. Variable credit. May be repeated up to a maximum of eight credits.

CE 598 Special Topics in Civil Engineering

Studies in advanced topics of current interest.

CE 599 Thesis Research F,W,S

Graduate students only. Credits as assigned; however, not more than 12 credits will be applied toward the requirements of the M.S. degree.



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Course Descriptions

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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Computer Science & Software Engineering

Professors Anderson, Bohner, Boutell, Chenoweth, Chidanandan, Clifton, Defoe, Laxer, Mellor, Mohan, Mutchler, and Wollowski

For current information on course offerings, see the department's web site:
www.cs.rose-hulman.edu.

CSSE 120 Introduction to Software Development 3R-3L-4C F, W, S
An introduction to procedural and object-oriented programming with an emphasis on problem solving. Students will solve problems by developing software in both an interpreted language (Python) and a compiled language (C). Problems may include visualizing scientific or commercial data, interfacing with external hardware such as robots, or solving numeric problems from a variety of engineering disciplines. Procedural programming concepts covered include data types, variables, control structures, arrays, and data I/O. Object-oriented programming concepts covered include object creation and use, object interaction, and the design of simple classes. Software engineering concepts covered include testing, incremental development, understanding requirements, and teamwork.

CSSE 220 Object-Oriented Software Development 3R-3L-4C F,W,S Prerequisite: CSSE 120
Object-oriented programming concepts, including the use of inheritance, interfaces, polymorphism, abstract data types, and encapsulation to enable software reuse and assist in software maintenance. Recursion, GUIs and event handling. Use of common object-based data structures, including stacks, queues, lists, trees, sets, maps, and hash tables. Space/time efficiency analysis. Testing. Introduction to UML.

CSSE 221 Fundamentals of Software Development Honors 3R-3L-4C F Prerequisite: A score of 4 or 5 on the APCS A exam or permission of instructor
This course is intended for students who have sufficient programming experience to warrant placement in an accelerated course covering the topics from CSSE 120 and CSSE 220. This course will satisfy the prerequisite requirements for courses that have CSSE 220 as a prerequisite.

CSSE 230 Data Structures and Algorithm Analysis 3R-3L-4C W,S Prerequisites: CSSE 220 or CSSE 221 or a score of 4 or 5 on the APCS AB exam, and MA 112
This course reinforces and extends students' understanding of current practices of producing object-oriented software. Students extend their use of a disciplined design process to include formal analysis of space/time efficiency and formal proofs of correctness. Students gain a deeper understanding of concepts from CSSE 220, including implementations of abstract data types by linear and non-linear data structures. This course introduces the use of randomized algorithms. Students design and implement software individually, in small groups, and in a challenging multi-week team project.

CSSE 232 Computer Architecture I 3R-3L-4C F, W Prerequisites: CSSE 120 and ECE 130
Computer instruction set architecture and implementation. Specific topics include historical perspectives, performance evaluation, computer organization, instruction formats, addressing modes, computer arithmetic, ALU design, floating-point representation, single-cycle and multi-cycle data paths, and processor control. Assembly language programming is used as a means of exploring instruction set architectures. The final project involves the complete design and implementation of a miniscule instruction set processor.

CSSE 241 Computing in a Global Society 2R-6L-4C Arr Prerequisite: CSSE 220 or CSSE 221

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

The ability to work with colleagues from other cultures and to work on international projects are key assets in today's job market. The centerpiece of this course is a real-world computing project that students develop in cooperation with peers from an institution of higher education in a foreign country. Exposes students to the procedures and complexities of working on projects that span many time-zones and cultures. Additionally, students examine the use and impact of computing in a global community. International travel is required; students will be expected to incur additional expenses (will vary depending on the project, institution, and country). May be repeated once (for free elective credit only) if the country involved is different.

CSSE290 Special Topics in Computer Science 1 ' 4C Arr. Prerequisite: Permission of instructor.

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 304 Programming Language Concepts 4R-0L-4C S Prerequisite: CSSE230 and MA275

Syntax and semantics of programming languages. Grammars, parsing, data types, control flow, parameter passing, run-time storage management, binding times, functional programming and procedural abstraction, syntactic extensions, continuations, language design and evaluation. Students will explore several language features by writing an interpreter that implements them.

CSSE 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Prerequisites: CSSE 220 or CSSE 221, and MA 222

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated Function Systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as MA 325.

CSSE 332 Operating Systems 3R-3L-4C W, S Prerequisites: CSSE 220 or CSSE 221, and CSSE 232

Students learn fundamental concepts of modern operating systems by studying how and why operating systems have evolved. Topics include CPU scheduling, process synchronization, memory management, file systems, I/O systems, privacy and security, and performance evaluation. Students implement parts of an operating system as a means of exploring the details of some of these topics.

CSSE 333 Database Systems 3R-3L-4C W Prerequisite: MA 275 and CSSE 230 (or concurrent enrollment in CSSE 230)

Relational database systems, with emphasis on entity relationship diagrams for data modeling. Properties and roles of transactions. SQL for data definition and data manipulation. Use of contemporary API's for access to the database. Enterprise examples provided from several application domains. The influence of design on the use of indexes, views, sequences, joins, and triggers. Physical level data structures: B+ trees and RAID. Survey of object databases.

CSSE 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA221 and programming experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as MA 335.

CSSE 351 Computer Graphics 4R-0L-4C Prerequisites: CSSE 220 or CSSE 221, and MA 221

Computer graphics algorithms, hardware and software. Line generators, affine transformations, line and polygon clipping, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and graphics standards. Programming assignments and a final project are required.

CSSE 371 Software Requirements and Specification 4R-0L-4C F Prerequisite: CSSE 230, RH 330, and Junior standing

Basic concepts and principles of software requirements engineering, its tools and techniques, and methods for modeling software systems. Topics include requirements elicitation, prototyping, functional and non-functional requirements, object-oriented techniques, and requirements tracking.

CSSE 372 Software Project Management 4R-0L-4C F Co-requisite: CSSE 371

Major issues and techniques of project management. Project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, quality, rework, negotiation, and conflict management. Professional issues including career planning, lifelong learning, software engineering ethics, and the licensing and certification of software professionals.

CSSE 373 Formal Methods in Specification and Design 4R-0L-4C S Prerequisite: CSSE230 and MA275

Introduction to the use of mathematical models of software systems for their specification and validation. Topics include finite state machine models, models of concurrent systems, verification of models, and limitations of these techniques.

CSSE 374 Software Architecture and Design 4R-0L-4C W Prerequisite: CSSE 371

Introduction to the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, and relationships between levels of abstraction.

CSSE 375 Software Construction and Evolution 4R-0L-4C S Prerequisite: CSSE 374

Issues, methods and techniques associated with constructing software. Topics include detailed design methods and notations, implementation tools, coding standards and styles, peer review techniques, and maintenance issues.

CSSE 376 Software Quality Assurance 4R-0L-4C S Prerequisite: CSSE 230

Theory and practice of determining whether a product conforms to its specification and intended use. Topics include software quality assurance methods, test plans and strategies, unit level and system level testing, software reliability, peer review methods, and configuration control responsibilities in quality assurance.

CSSE 377 Software Architecture and Design II 4R-0L-4C F Pre: CSSE 374 or consent of instructor

This is a second course in the architecture and design of complete software systems, building on components and patterns. Topics include architectural principles and alternatives, design documentation, relationships between levels of abstraction, theory and practice of human interface design, creating systems which can evolve, choosing software sources and strategies, prototyping and documenting designs, and employing patterns for reuse. How to design systems which a team of developers can implement, and which will be successful in the real world.

CSSE 403 Programming Language Paradigms 4R-0L-4C F Prerequisite: CSSE304

A survey of some current and emerging programming languages, focusing on unique language paradigms/ways of structuring solutions or manipulating data. Examples of paradigms include dynamic programming languages, object-oriented programming, highly parallelizable code, and functional programming. Emphasizes developing independent learning techniques that will allow students to acquire skills in new languages quickly. Students will develop basic skills in at least three different languages representing distinct paradigms. They will also be exposed to a selection of other languages. Includes a substantial team project.

CSSE 404 Compiler Construction 4R-0L-4C S Prerequisites: CSSE 232, CSSE 304, and CSSE/MA474

Theory and practice of programming language translation. Lexical analysis, syntax analysis, parser generators, abstract syntax, symbol tables, semantic analysis, intermediate languages, code generation, code optimization, run-time storage management, error handling. Students will construct a complete compiler for a small language.

CSSE 413 Artificial Intelligence 4R-0L-4C Prerequisite: CSSE 230

Students investigate how to model and implement intelligent behavior using computers. Topics are chosen from how machines can: solve problems; reason and use knowledge; learn from experience; and perceive and act. Students explore these topics by implementing many of the ideas in software. Readings are drawn both from a textbook and from technical papers in recent conferences and journals.

CSSE 432 Computer Networks 4R-0L-4C Prerequisite: CSSE 220 or CSSE 221

Organization, design, and implementation of computer networks, especially the Internet. Network protocols, protocol layering, flow control, congestion control, error control, packet organization, routing, gateways, connection establishment and maintenance, machine and domain naming, security. Each of the top four layers of the Internet protocol stack: application (FTP, HTTP, SMTP), transport (TCP, UDP), network (IP), link (Ethernet).

CSSE 433 Advanced Database Systems 4R-0L-4C Prerequisite: CSSE 333

Topics selected from object-oriented databases, object-relational databases, query processing, transactions, transaction logging, concurrency control, database recovery, parallel and distributed databases, security and integrity, data mining and data warehousing.

CSSE 442 Computer Security 4R-0L-4C W Prerequisites: CSSE 332 and MA 275

This course introduces ethical, theoretical, and practical issues of information security in computing systems. Implications of relevant professional codes of ethics are a recurring theme of the course. Foundational topics include access control matrices and standard system models, as well as policies for security, confidentiality, and integrity. Implementation issues include key management, cipher techniques, authentication, principles of secure design, representation of identity, access control mechanisms, information flow, life cycle issues, and formal evaluation and certification techniques. Additional topics include malicious logic, vulnerability analysis, and auditing. Computer network attack techniques are discussed and explored in a closed environment to motivate and inform discussion and exploration of computer network defense techniques.

CSSE 451 Advanced Computer Graphics 4R-0L-4C Prerequisite: CSSE 351

Advanced topics in computer graphics. Topics will be drawn from current graphics research and will vary, but generally will include ray tracing, radiosity, physically-based modeling, animation, and stereoscopic viewing. Programming assignments and a research project are required.

CSSE 453 Topics in Artificial Intelligence 4R-0L-4C Prerequisite: CSSE 413

Advanced topics in artificial intelligence. Topics will vary. Past topics have included machine game playing and machine learning. May be repeated for credit if topic is different.

CSSE 461 Computer Vision 4R-0L-4C Prerequisites: CSSE 220 or CSSE 221, and MA 221 (MA 371 or MA 373 recommended)

An introduction to 3D computer vision techniques. Both theory and practical applications will be covered. Major topics include image features, camera calibration, stereopsis, motion, shape from x, and recognition.

CSSE 463 Image Recognition 4R-0L-4C W Prerequisites: Junior standing, MA221 and programming experience

Introduces statistical pattern recognition of visual data; low-level visual feature extraction (color, shape, edges); clustering and classification techniques. Applies knowledge to various application domains through exercises, large programming projects in Matlab, and an independent research project. Familiarity with probability distributions will be helpful, but not required.

CSSE 473 Design and Analysis of Algorithms 4R-0L-4C Prerequisites: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as MA 473.

CSSE 474 Theory of Computation 4R-0L-4C Prerequisites: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as MA 474.

CSSE 479 Cryptography 4R-0L-4C Prerequisites: CSSE 220 or CSSE 221, and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography. Same as MA 479.

CSSE 481 Web-Based Information Systems 4R-0L-4C Prerequisite: CSSE 230

In this course, students learn about several aspects of research: thinking creatively about interesting research problems, researching existing work in a chosen area, and keeping current in a field. Students are exposed to the process of research by writing a pre-proposal for a project that advances the web. Projects either develop new web-technologies or applications or investigate a topic of importance. Based on feedback received, groups of students write a research proposal which goes through a formal peer review process. Approved projects are pursued for the remainder of the quarter. Students present current research as well as give a final presentation of their group project. Selected web-technologies are introduced; in the past, these have included CGI programming and XML technologies.

CSSE487 Senior Research Project I 4C Arr Prerequisite: RH330 and senior standing

CSSE488 Senior Research Project II 4C Arr Prerequisite: CSSE487

CSSE489 Senior Research Project III 4C Arr Prerequisite: CSSE488

Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arr Prerequisite: Permission of instructor

Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arr Prerequisite: Permission of instructor and department head

Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arr Prerequisite: Permission of instructor and department head

CSSE 493 Undergraduate Research in Software Engineering 1-4C Arr Prerequisite: Permission of instructor and department head

Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arr Prerequisite: RH 330 and Permission of instructor and department head

CSSE 495 Senior Thesis II 4C Arr Prerequisite: CSSE 494

CSSE 496 Senior Thesis III 4C Arr Prerequisite: CSSE 495

Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Project I 4C F Prerequisite: CSSE 371

CSSE 498 Senior Project II 4C W Prerequisite: CSSE 374 and CSSE 497

CSSE 499 Senior Project III 4C S Prerequisite: CSSE 498

Group software engineering project requiring completion of a software system for an approved client. Tasks include project planning, risk analysis, use of standards, prototyping, configuration management, quality assurance, project reviews and reports, team management and organization, copyright, liability, and handling project failure.



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Course Descriptions

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

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Electrical & Computer Engineering

ECE 130 Introduction to Logic Design 4R-0L-4C F,W,S Pre: None
Combinational logic analysis and design, Boolean algebra, gate-level optimization, switch-level circuits, propagation delay, and standard combinational components. Sequential circuit analysis and design, flip-flops, timing diagrams, registers, counters, and finite state machine controllers. Design projects using circuit simulation and implementation in hardware.

The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

Mutual inductance. First- and second-order circuits. Laplace transform. Applications in the s-domain. Bode diagrams. Passive and active filters. Two-port networks. Integral laboratory includes circuit design problems.

Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

Review of matrix and differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical, mechanical, and thermal systems. Matlab and Simulink. Integral laboratory.

A course designed for engineers (other than electrical or computer) covering analysis of passive DC circuits, introduction to op-amps, steady-state sinusoidal circuit analysis and power in AC systems. EE or CPE majors may not take this course as a free elective.

A course designed for engineers (other than electrical or computer) covering AC power, three-phase systems, magnetic circuits, transformers, machines, strain gauges, RTDs and thermocouples, noise and shielding, and feedback systems. Integral laboratory. EE or CPE majors may not take this course as a free elective.

Sophomore Engineering

ECE 230 Microcontrollers and Computer Architecture 3R-3L-4C F, W, S Pre: ECE130, CSSE120

Microcontroller architecture, instruction sets, assembly language programming, interrupts, and device interfacing. Integral laboratory and design project.

ECE 250 Electronic Device Modeling 3R-3L-4C F,W,S Pre: ECE 204, MA 222

Modeling, analysis, and simulation of electronic circuits that contain two-terminal and three-terminal semiconductor devices. Large-signal, biasing, and small-signal analysis models. Introduction to wave shaping circuits, switching circuits, and amplifiers. Integral laboratory.

ECE 300 Continuous-Time Signals Systems 3R-3L-4C F,W,S Pre: ECE 205

Signal modeling. Fourier series and Fourier transforms. Response of systems to periodic and aperiodic signals. Filter characterization and design. Ideal and practical sampling. Use of numerical analysis software. Integral laboratory

ECE 310 Communication Systems 3R-3L-4C F,W,S Pre: ECE 300, MA 381

Transmission of information over bandlimited, noisy communication channels. Line codes, probability of error, intersymbol interference. Modulation techniques, synchronization and frequency conversion. Discussion of a current ethical issue. Integral laboratory.

ECE 320 Linear Control Systems 3R-3L-4C F,W,S Pre: ECE 300 and either ECE 230 or ME 430

Analysis of linear control systems using classical and modern control theories in both continuous and discrete time. Plant representation, closed loop system representation, time response, frequency response, concept of stability. Root locus, Bode, and Nyquist methods. Computer modeling and simulation of feedback systems, implementation of discrete-time algorithms on microcontrollers.

ECE 331 Embedded System Design 3R-3L-4C F,S Pre: CSSE 232, ECE 250

Microcontroller architecture. Software development in both assembly language and the C programming language. Real-time event measurement and generation. Interrupt design and applications. Interfacing with peripheral digital and analog devices. Integrated development and debugging environment. Design and implementation of embedded systems for control, measurement, and display, etc. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 332 Computer Architecture II 4R-0L-4C F,S Pre: CSSE 232

Pipelining, memory hierarchy, busses, instruction level parallelism, cost-performance tradeoffs, and review of new topics in areas of computer architecture or parallel processing. Team research project. Complements CS 332.

ECE 333 Digital Systems 3R-3L-4C F,W,S Pre: ECE 130, ECE 250

Capabilities and limitations of digital CMOS logic devices. Design and evaluation of combinational and sequential logic circuits using Programmable Logic Devices. System integration with multiple components (FPGA, GAL, discrete components). CAD tools for design entry, timing simulation, and mapping to target devices. Troubleshooting using laboratory instrumentation. Laboratory notebooks. Informal reports. Integral laboratory.

ECE 340 Electromagnetic Fields 4R-0L-4C F,W Pre: ECE 204, MA 222

Static and dynamic fields. Electric and magnetic properties of materials. Energy, force and power. Resistors, capacitors, and inductors. Application in sensing and actuation. Maxwell's equations. Introduction to electromagnetic waves. Use of vector calculus and numeric approximation. Technical reports and/or term papers.

ECE 341 Electromagnetic Waves 4R-0L-4C W,S Pre: ECE 340

Wave propagation and reflection. Power and lossy materials. Quasistatic analysis. Steady-state and transient analysis of transmission lines. Application in high-speed systems. Introduction to antennas. Technical reports and/or term papers.

ECE 342 Introduction to Electromagnetic Compatibility 3R-3L-4C F,W Pre: ECE 300 and Computer Engineering Major

Electromagnetic compatibility (EMC) regulations and measurement. Frequency behavior of passive components. Electromagnetic fields and waves. Transient behavior of transmission lines. Dipole and monopole antennas. Four coupling mechanisms: electrical and magnetic fields, common impedance, and electromagnetic wave. Conducted emissions. Radiated emissions. Electromagnetic shielding and grounding.

ECE 351 Analog Electronics 3R-3L-4C F,W,S Pre: ECE 205, ECE 250

Amplifier design and analysis including discrete and integrated circuit topologies. Cascaded amplifier, input and output stages, frequency response. Linear and non-linear op-amp circuits. Introduction to the non-ideal

properties of op-amps. Integral laboratory.

ECE 361 Engineering Practice 1R-3L-2C F,W Pre: ECE 200

Creativity, project design specifications, team roles, effective conduct of team meetings, written and oral communication skills, ethics and professionalism, completion of team project(s).

ECE 362 Principles of Design 3R-0L-3C W, S

Pre for EE: ECE160, ECE250, ECE300, ECE340

Pre for CPE: ECE160, ECE250, ECE300

Pre for CS and SE majors: CSSE 374

Pre for ME majors: EM 103, ES 205, and ECE 207

A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

ECE 370 Power & Energy Systems 3½R-1½L-4C F, W Pre: ECE204

Analysis of generation systems consisting of: modeling of synchronous and induction generators, examination of fossil, nuclear, hydroelectric, solar, wind, and fuel cell technologies. Analysis of transmission and distribution systems consisting of modeling: power transformers, transmission lines, switchgear, and protection systems. Analysis of customer systems consisting of modeling: induction motors, linear and non-linear loads.

ECE 371 Sustainable Energy Systems 3R-3L-4C F, W Pre: ECE204

Conventional and modern sources of energy for power generation in electric power industry with the imposed economic, regulatory, and environmental constraints. Wind, solar-photovoltaic, micro-hydropower, and fuel cell systems. Integral laboratory.

ECE 380 Discrete-Time Signals and Systems 4R-0L-4C F,W,S Pre: ECE 300

System properties: linearity and time-invariance. Sampling and reconstruction. Convolution in discrete-time systems. Z-transform, FIR and IIR filters. Discrete-time filter design. Discrete Fourier transform.

ECE 398 Undergraduate Projects 1-4C Arranged Pre: Consent of instructor

Special design or research projects.

ECE 410 Communication Networks 4R-0L-4C Pre: Senior standing or consent of instructor

Layered architectures. Circuit and packet switching. ISO Reference Model. Point-to-point protocols, error control, framing. Accessing shared media, local area networks. Virtual circuits, datagrams, routing, congestion control. Reliable message transport, internetworking.

ECE 412 Software Defined Radio 4R-0L-4C S Pre: ECE 380 and ECE 310 or consent of instructor

A software-defined radio (SDR) is characterized by its flexibility: Simply modifying software can completely change the radio's functionality. This course addresses many of the choices an SDR designer must make to build a complete digital radio. Topics could include: modeling corruption, (de)modulation, AGC, filtering, bits to symbols, carrier and timing recovery, pulse shaping, equalization, coding, noise figure for the RF front-end, and clock-jitter of the A/D. As a course project students will design and simulate a complete software-defined radio.

ECE 414 Wireless Systems 4R-0L-4C Pre: ECE 310

Introduction to mobile radio communications with application to cellular telephone systems, wireless networks, and personal communication systems. System design, propagation, modulation, spread spectrum, coding, and multiple-access techniques.

ECE 415 Wireless Electronics 2R-6L-4C Pre: Consent of instructor

Design, fabrication, and testing of a high frequency transmitter-receiver system including but not limited to oscillators, mixers, filters, amplifiers, and matching networks. Integral laboratory.

ECE 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

ECE 418 Fiber Optic Systems 4R-0L-4C W Pre: ECE 310 or consent of instructor

Analysis and design of common photonic systems such as fiber optic communication links, optical sensing systems, and optical signal processors. Topics include component overview, basic system design, and expected degradations along with mitigation techniques. An oral presentation of a research project is required.

ECE 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for

layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ECE 420 Nonlinear Control Systems 3R-3L-4C Pre: ECE 320 or ME 406

Modeling nonlinear systems. Use of modeling software to design nonlinear control systems. Intuitive control strategies. Fuzzy control, computer and hardware implementation of fuzzy controllers, adaptive fuzzy control. Integral laboratory.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Pre: ECE 250 for ECE students, consent of instructor for other students.

Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 451 Nonlinear Electronics 3R-3L-4C Pre: ECE 351

Analysis and design of Class C and D amplifiers, high-power switching amplifiers, negative-resistance oscillators, low-noise transistor and operational amplifier circuits, and parametric amplifiers. Emphasis on nonlinear and time-varying circuit analysis and design techniques. Integral laboratory.

ECE 452 Power Electronics 3R-3L-4C Pre: ECE 250

Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Pre: ECE 351

Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, S Pre: ECE 362

A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C F, W, S

Pre for EE: ECE310, ECE320 ECE333, ECE341, ECE351, ECE370 or ECE371, ECE380, ECE460

Pre for CPE: CSSE332, ECE331, ECE332, ECE333, ECE342, ECE351, ECE380, ECE460

Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W, S Pre: ECE461

Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Pre: Junior class standing

Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers.

ECE 470 Power Systems I 3R-3L-4C Pre: ECE 370

Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C Pre: ECE 370

Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C Pre: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C Pre: Senior standing or consent of instructor

Principles of interconnected operation of power systems. Optimum scheduling of generation using economic

dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/PH 437 Introduction to Image Processing 3R-3L-4C Pre: MA 222 and Junior standing

Basic techniques of image processing. Discrete and continuous two-dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory. Same as PH 437.

ECE 481 Electronic Music Synthesis 4R-0L-4C Pre: ECE 380

Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Pre: ECE 380 and MA 381

Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Pre: Consent of instructor and department head

Topics of current interest to undergraduate students.

ECE 498 Engineering Projects and Design 2R-6L-4C Pre: Senior standing

Aspects of design and design presentations. Development of preliminary design and proposal for hardware project. Formal proposal and component selection. Construction, testing, and performance demonstration of previously designed project. Formal final report and oral presentation.

UNDERGRADUATE-GRADUATE COURSES

ECE 510 Error Correcting Codes 4R-0L-4C Pre: Graduate standing, or ECE310 with a grade of B or better, or consent of instructor

Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C Pre: Graduate standing, or ECE 310 and MA 381 with grades of B or better, or consent of instructor

Design of digital communication systems. Topics to be chosen from: Channel characterization, data compression and source coding, baseband data transmission, noise modeling, probability of error, optimal receiver structures, modulation methods, synchronization.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

Students enrolled in EP510, ME516, ECE516, CHE505, BE516 must do project work on a topic selected by the instructor.

ECE 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Students enrolled in EP511, ME519, ECE519, CHE519, BE516 must do project work on a topic selected by the instructor.

ECE 520 Discrete-Time Control Systems 3R-3L-4C W Pre: Graduate standing, or ECE 320 or ME 406 with grade of B or better, or consent of instructor

Digital control. Z-transform, sampling systems, sampled data control systems. Digital compensator (filter) design. Compensator sign pre- and post-conditioning. Discrete state-variable model. Integral laboratory.

ECE 521 Modern Control Systems 3R-3L-4C Pre: Graduate standing, or ECE 320 or ME 406 with a grade of B or better, or consent of instructor

State variable modeling of physical systems. Lagrangian formulations, applications of linear algebra, controllability, observability, state feedback design, design of observers. Laboratory projects emphasize control system design using state variable methods. Integral laboratory.

ECE530 Advanced Microcomputers 3R-3L-4C Pre: Graduate Standing, or ECE430 with a grade of B or better, or ECE331 with a grade of B or better, or consent of instructor.

Design of a microcomputer using a big honkin' microprocessor. Architecture and assembly programming. Integral laboratory.

ECE531 Microprogrammable Microcomputers 3R-3L-4C Pre: Graduate standing, or ECE430 with a grade of B or better, or consent of instructor

Architecture and application of microprogrammed CPU's. Microprogrammed control, hardwired control. Students will be required to develop their own microprogrammed CPU. Integral laboratory.

ECE532 Advanced Computer Architecture 4R-0L-4C Pre: Graduate standing, or ECE332 with a grade of B or better, or both ECE530 and ECE531, or consent of instructor

Selected topics in computer architecture depending on interests of class and instructor. Projects investigating current issues in computer architecture.

ECE533 Programmable Logic System Design 3R-3L-4C Pre: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Digital system-on-chip design techniques, including an advanced hardware description language, test-benches and verification, area and timing optimization, embedded microprocessors, and design for testing. Integral laboratory using contemporary CAD tools and FPGA devices.

ECE534 High-Speed Digital Design 4R-0L-4C W Pre: Graduate Standing, or ECE340 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor

Signal integrity issues in high-speed digital systems at printed-circuit board (PCB) and chassis levels. Frequency spectrum of digital signals. Frequency behaviors of passive components. Behavior models of drivers and receivers. Transient behaviors of transmission lines. Time-domain reflectometry. Signal reflection and ringing on printed-circuit board. Impedance discontinuity and matching. Load termination techniques. Capacitive and inductive crosstalk. Ground noise. Power plane noise and resonance. High-speed PCB design guidelines. PCB simulation tools.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C Pre: CSSE 232 with grade of B or better, or ECE333 with either a grade of B or better, or consent of instructor, or graduate standing

Methods of designing dependable electronic systems using fault-tolerance techniques. Dependability attributes: reliability, availability, safety, fault modeling. Techniques to evaluate electronic systems' dependability such as reliability block diagrams, Markov processes, FMECA (failure mode effects and critically analysis), and FTA (fault tree analysis). Design and analysis of fault-tolerant systems using hardware or information or time or software redundancy.

ECE540 Antenna Engineering 3R-3L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.

Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Wave-guide structures, scattering parameters, passive components, active components, computer-aided design of amplifiers, oscillators and mixers, microwave/millimeter-wave systems, microwave and millimeter-wave integrated circuits.

ECE542 Advanced Electromagnetics 4R-0L-4C Pre: Graduate standing, or ECE341 with a grade of B or better, or consent of instructor

Maxwell's equations, power and energy, material properties, waves, reflections, radiation, EM field theorems, boundary value problems, skin effect.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor

Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE550 Linear Active Networks 3R-3L-4C Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Indefinite admittance matrix and expansion of the two-port methods of linear network analysis and design. Brune's tests. Llewellyn's stability criteria for two-port networks. Optimum terminations and mismatch design. Neutralization and unilateralization of amplifiers. Oscillators. Computer-aided design and analysis are

emphasized. Integral laboratory.

ECE551 Digital Integrated Circuit Design 3R-3L-4C Pre: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier design and op-amp circuits. Introduction to mixed-signal circuit design such as switch-capacitors, A/D, or D/A systems. Integral laboratory and design project.

ECE553 Radio-Frequency Integrated Circuit Design 3R-3L-4C Pre: Graduate standing, or ECE310 and ECE351 with a grades of B or better, or consent of instructor

Design, analysis, and physical layout of high-frequency analog integrated-circuits for modern RF transceivers. Circuit design for each primary transceiver component. General issues such as impedance matching and design of inductors on integrated circuits. Integral laboratory and design project.

ECE554 Instrumentation 4R-0L-4C Pre: Graduate standing, or ECE351 with a grade of B or better, or consent of instructor

Transducers and their applications. Instrumentation amplifiers. A/D and D/A converters. Shock protection. Generation, recording and analysis of biological potentials (ECG, EMG, EEG). Ultrasound techniques and instrumentation. X-ray CAT techniques. Project involving the design of a significant instrument will run throughout the course. No laboratory, but emphasis on computer simulation of the circuits studied.

ECE556 Power Electronics: DC Power Supplies 3R-3L-4C W Pre: Graduate standing, or ECE351 with a grade of B or better or consent of instructor

Analysis and design of AC-DC and DC-DC converters. Linear, basic switching, charge-pump, and fly-back topologies. Introduction to devices used in a power switching supplies. Thermal management. Integral laboratory.

ECE580 Digital Signal Processing 4R-0L-4C W Pre: Graduate standing, or ECE380 and MA381 with grades of B or better, or consent of instructor. MA367 with a grade of B or higher recommended.

Digital filters. Fundamental concepts of digital signal processing. Analysis of discrete-time systems. Sampling and reconstruction. Theory and application of z-transforms. Design of recursive and nonrecursive digital filters. Window functions. Discrete Fourier transforms and FFT algorithm.

ECE 581 Digital Signal Processing Projects 2R-2L-2 or 4C Pre: ECE 580 or concurrent registration

Computer-aided design of digital filters and other DSP modules. Software and hardware realization using modern DSP chips. DSP chip architectures, C-language programming, and interfacing techniques. Optional advanced project may be done to earn four credit hours; otherwise two credit hours are given. Integral laboratory.

ECE 582/PH 537 Advanced Image Processing 3R-3L-4C Pre: CSSE 220 or ME 323 or ECE 380 or consent of instructor; MA 221

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as PH 537.

ECE 583 Pattern Recognition 3R-3L-4C S Pre: MA 381 with a grade of B or better, or consent of instructor, or graduate standing

Bayesian decision theory, parameter estimation, non-parametric techniques, linear discriminant functions, supervised learning, unsupervised learning and clustering, artificial neural networks, ensemble classifiers.

ECE 597 Special Topics in Electrical Engineering 4C Pre: Consent of instructor

Special topics of current interest to graduate students and senior undergraduates.

ECE 598 Thesis Research 1-4C arranged

Thesis topic selected in consultation with adviser. Graduate students only.



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Engineering Management

Professors Downing, Kline, Mason, Schumacher and Stamper

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only

Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4C

Pre: Junior, Senior, or consent of instructor

Explores design processes characterized by interdisciplinary activity and focus on commercial success. Includes basic design processes with emphasis on data collection and specification, with special attention to the voice of the customer. Develops at least three creativity techniques and identifies sources of ideas for successful innovation. Demonstrates procedures for assessing markets and establishing conceptual business models and describes the fundamentals of project planning and management. Addresses aspects of professional practice -- - ethics, communication, contemporary issues, social impacts, global context and team work-in the design process. Uses a team project on reverse engineering to tie together course objectives, and identifies an entrepreneurial or appropriate externally sponsored project topic for later courses. Prerequisite: Junior standing or consent of instructor. (Students completing MG 461 may not receive credit for ME 470.)

EMGT462 Multidisciplinary, Entrepreneurial Design II: Expand the Concept 2R-XL-XC

Pre: **MG 461 or consent of instructor**

Expands on the basic design process issues such as solution identification and selection and the assessment of trade-offs and impacts on health, safety, quality, environment, sustainability, and manufacturability. Applies design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC

Pre: **MG 462 or consent of instructor**

Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C, Technical

Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations.

EMGT497 Special Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular engineering management topics of current interest and/or new courses for engineering management and other students. May require consent of instructor or specific prerequisites.

EMGT520 Accounting for Technical Managers 4R-0L-4C - Management

An introduction to accounting principles and practices as related to financial and managerial accounting. The uses of accounting information and the means by which pertinent accounting data are gathered and analyzed for internal purposes and management decisions.

EMGT521 Financial Management in a Technical Environment 4R-0L-4C, Management

A comprehensive survey of financial concepts, techniques, instruments, and procedures which are related to the financial structure, assets management, dividend policy, and the capital budgeting decisions of a firm. Basic skills in financial analysis are developed. Operations of domestic and international financial markets are covered.

EMGT522 Organizational Management 4R-0L-4C - Management

Review of fundamental activities (planning, organizing, leading, controlling) related to the management of organizations. The concepts and techniques for maximizing the effectiveness of human resources in the achievement of organizational and project goals are emphasized. Topics include communication, team process, motivation, selection, development, and appraisal. Special focus is given to the management of human resources in a technical environment.

EMGT523 Marketing Issues in a Technical Environment 4R-0L-4C, - Management

A study and overview of the components of marketing principles and how those mesh with management in a technical environment. Topics will include activities associated with product, price, promotion, and distribution and how these impact the technical manager from idea generation through delivery to and service for the customer.

EMGT524 Production/Operations Management 4R-0L-4C, Technical or Management

To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities, and the use of a business simulation exercise and project to illustrate class concepts.

EMGT526 Technology Management and Forecasting 4R-0L-4C, Technical or Management

Elements of managing the growth and operation of the technological systems. Technology forecasting tools including expert methods, quantitative trend analysis, simulation, and gaming. Consideration of secondary forecasts, especially those of social and economic nature. Techniques for enhancing creativity, managing multi-disciplinary projects and impact assessment techniques are considered. Computer-based forecasting tools are applied.

EMGT527 Project Management 4R-0L-4C - Technical or Management

Addresses the major issues and techniques of project management, including team building, project evaluation and selection, scheduling techniques, quality management, development of negotiation and conflict management skills. Also examines project management success factors. Uses a large scenario planning exercise and several case studies to illustrate course content. Can be used as part of the technical or management core.

EMGT531 Economics for Technical Managers 4R-0L-4C - Management

Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C - Management

Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-OL-4C - Management

The core of this course is the presentation of the Constructivist theory of communication and its application. Students are exposed to ethnographic interview methods and the concept of culture shock using the BAFA role-play simulation. Discussion of organizational culture includes a review of publications on this topic, the impact of culture on organizations, as well as strategies for change. May be used as a management core class.

EMGT534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing Technical or Management

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as MA 534.

EMGT535 Globalization, Strategy and Organizational Change 4R-OL-4C, Management

Reviews the strategy literature and the issues surrounding strategy implementation in the context of organizational change. Includes a team project that explores the strategic implications of globalization for specific industries during the next 10 years and the construction of scenarios as a tool for understanding and communication. Individual students will develop and evaluate strategy for a specific organization within the scenarios developed in the team project.

EMGT537 Organizational Theory and Design 4R-OL-4C, Management

Presents theory, examples, and best practices of organizational design for success. Strategies for planning, organizing and controlling organizations in various life cycles stages, technological levels, and international domains are critically important for organizational success. Discusses proper assessment of internal and external organizational environments, managing dynamic processes, and dealing with innovation and change to plan for growth and expansion of organizations considering outsourcing, globalization, communication and information technology changes. Theory is presented to include politics, conflict, and change management as issues organizations must manage.

EMGT540 Fundamentals of Engineering Management 4R-OL-4C, Technical

Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior. Case studies, projects and role playing activities demonstrate the importance of the concepts.

EMGT586 Supply Chain Management 4R-OL-4C, Technical

Examines disruptions to traditional operations within supply chains due to changes in both technology and globalization. Shows how relationships between suppliers, customers, and competitors have changed dramatically to affect the entire manner in which organizations perform their manufacturing and business operations. Describes product supply chain complexity and the implications of expanding global customer bases, increasing supplier dependence, and larger ranges of locations and customers. Outcomes include the abilities to identify and define the critical components of supply chains, apply best practices in the buyer-seller relationship and understand why managing a supply chain is an important strategic capability for an organization.

EMGT587 Systems Engineering 4R-OL-4C, Technical

Introduces system engineering and analysis techniques, including the systems life cycle, system design procedures, risk analysis, analysis methods including reliability and maintainability. Provides applications for mechanical, electrical and a wide variety of other systems. Uses Visio or CORE software to create IDEFO drawings and other documentation for system design.

EMGT588 Quality Management 4R-OL-4C - Technical

Introduction to quality for the technical manager including management principles and technical methods. Balance will be approximately 65% technical methods and 35% management concepts. Management topics focus on the concept of total quality (TQ) as it applies to technology based businesses including design, manufacturing and service activities. Contemporary quality philosophies are reviewed including Deming and Taguchi. Technical tools and methods are presented including basic statistical concepts, control charts for variable and attributes, process capability studies, six sigma, and tools for design and process improvement. Case studies and class labs will be used to highlight key topics.

EMGT589 Manufacturing Systems 4R-OL-4C - Technical

Provides a comprehensive introduction to manufacturing systems covering the "behavior laws" at work in batch

production or assembly lines. Includes production strategy, scheduling, and control methods and detailed analysis of fundamental manufacturing measures such as cycle time, throughput, capacity, work-in-process, inventory, and variability. Explores historical practices and the natural behaviors that are described in "laws for manufacturing" that help managers understand basic "factory physics".

EMGT590 Integrated Project

Credits as assigned; however, not more than 8 credits can be applied to MS degree requirements

Pre: Completion of technical component and business core or permission of instructor

The integration of business and technical considerations in new product development. The identification of managerial and engineering challenges faced in developing a commercially viable new product within the context of a rapidly changing and highly competitive business environment. Readings, case studies and individual projects dealing with strategic planning, entrepreneurship, new product development, and related topics. The focus is on a major team project. This integrated project must include the identification of a new product including all relevant business and technical issues and the development of a detailed plan for profitably bringing this new product to market. A final report with oral presentations is required.

EMGT597 Special Management Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular management topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.

EMGT598 Special Technical Topics in Engineering Management (1-4)R-0L-(1-4)C

Examines particular technical topics of current interest and/or new courses for engineering management and other graduate students and upper level undergraduates. May require consent of instructor or specific prerequisites.



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Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Engineering Mechanics

All courses in the engineering mechanics area are the responsibility of the Civil and Mechanical Engineering Departments.

CLSK 100 College and Life Skills 1R-0L-1C F Pre: None

This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

EM 101 Statics 2R-0L-2C W Pre: None

Covers static force analysis. Introduces scalars and vectors with applications to the study of forces, moments, and couples. Stresses free body diagrams with engineering examples.

EM 103 Introduction to Design 1R-2L-2C S Pre: None

Introduces the engineering design process including problem definition, analysis, alternate solutions, specifications of final solution, and techniques of oral and written communications. Stresses the importance of teamwork through group design efforts.

EM 104 Graphical Communications 1R-2L-2C F Pre: None

Introduces the basic techniques used in engineering and scientific communication. Topics will include sketching of pictorials, computer-aided drawing, orthographic drawings, auxiliary views, reading engineering drawings and using electronic forms of communication.

EM 120 Engineering Statics 4R-0L-4C F,S Pre: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, shear and bending moment diagrams, friction, and area moments of inertia. Emphasizes free-body diagrams.

EM 121 Statics and Mechanics of Materials I 4R-0L-4C F,S Pre: MA 111

Covers two- and three-dimensional force systems, equilibrium, structures, distributed forces, and strength and elastic deflection of engineering materials due to loads applied axially. Emphasizes free-body diagrams.

EM 202 Dynamics 4R-0L-4C F Pre: MA 112 and EM 120 or PH 111

Kinematics and kinetics of particles in space and rigid bodies in plane motion. Applications of the principles of Newton's laws, work-energy, impulse-momentum, and conservation laws to solutions of simple two-dimensional dynamics problems.

EM 203 Mechanics of Materials 4R-0L-4C F,W Pre: EM 120

Strength and elastic deflection of engineering materials due to loads applied axially, in torsion, in bending, and in shear. Combined stresses and principal stresses. Applications to design of beams and shafts.

EM 204 Statics and Mechanics of Materials II 4R-0L-4C F,S Pre: EM 121

Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disiplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

EM 301 Fluid Mechanics 4R-0L-4C S Pre: EM 202

Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

***EM403 Advanced Mechanics of Materials 4R-0L-4C S Pre: EM 203 or EM 204**

Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

EM 406 Vibration Analysis 4R-0L-4C F Pre: ES 205

Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

Undergraduate-Graduate Courses

***EM 501 Topics in Fluid Mechanics 4R-0L-4C Arr Pre: ME401 or consent of instructor**

Course may be repeated for different topics in fluid mechanics.

***EM 502 Advanced Dynamics 4R-0L-4C Pre: ES 205**

Kinematics and dynamics of particles and rigid bodies in two- and three-dimensional motion. Includes Lagrangian and Hamiltonian formulation of equations of motion. Applications to conservative, nonconservative, holonomic and non-holonomic systems.

***EM 503 Advanced Vibration Analysis 4R-0L-4C W Pre: EM 406**

Dynamic analysis of multiple-degree-of-freedom lumped parameter vibrating systems as well as continuous systems. Lagrange's equations of motion. Applications include numerical methods and matrix formulation. Introduction to nonlinear and random vibration analysis. Methods of Rayleigh and Rayleigh-Ritz.

***EM 505 Theory of Elasticity 4R-0L-4C Pre: EM 203 or EM 204**

Introduces the classical formulation of problems in elasticity. Emphasizes the derivation and the applications of the basic constitutive equations of elasticity such as strain-displacement, equilibrium, compatibility, and stress-strain. Covers St. Venant's problems, energy principles, and variational methods.

***EM 508 Energy Methods in Engineering Mechanics 4R-0L-4C Pre: EM 403 and MA 330**

General concepts and principles in mechanics, conservative mechanical systems, and variational methods. Applications to deformable bodies.

*May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.



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Course Descriptions

CATALOG HOME

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

Engineering Physics

Professors: Bunch, Ditteon, Duree, Granieri, Joenathan, Kirkpatrick, Kirtley, Lepkowicz, Letfullin, McInerney, Moloney, Siahmakoun, Syed, Wagner, and Western.

Note: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W Pre: PH113
Scaling laws in small systems, basics of quantum mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, nanomechanics, cantilever oscillation, atomic-force microscope (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors.

EP 290 Directed Study Credit arranged Pre: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S Pre: EP280
Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, nanoscale heat: conduction, convection, and radiation. Nanophotonics in metals and semiconductors, surface Plasmon resonance and applications, photonic bandgap crystals, basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode and bipolar transistor. The project is a team exercise.

EP 408 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor
Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing
Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Same as ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Pre: EP 410 or equivalent course
Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Same as ME 419, ECE419, and CHE419.

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

EP 415 Engineering Physics Projects I 4C S Pre: RH 330 and consent of the instructor

Team-oriented and/or independent design project work on selected topics in any engineering discipline but related to concepts to strengthen both the application and physics and engineering, design of project, building of prototype, experiments to test components and systems, and market analysis.

EP 416 Engineering Physics Projects II 4C F Pre: Consent of the instructor

Follow up course to EP415. To be taken as a sequence from the same department where EP415 was taken.

EP 417 Engineering Physics Projects III 2R-6L-4CW Pre: Consent of the instructor

Follow up course to EP416. To be taken as a sequence from the same department where EP415 and EP416 were taken.

EP 470 Special Topics in Engineering Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Pre: PH 405 or ECE 250

Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devices and lasers. Laboratory is a design project, the production and characterization of a diode, bipolar transistor and MOSFET. The project is a team exercise. Students must do additional project work on a topic selected by the instructor.

EP 508 Microsensors 3R-3L-4C S Pre: JR or SR standing, and consent of instructor

Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Same as ME516, ECE516, CHE505, and BE516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Pre: EP410/510 or consent of instructor

Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Same as ME 519, ECE 519, and CHE 519.

EP Electives:

Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Geology

GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Pre: CHEM 111 or CHEM 105

Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.

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- Chemical Engineering
- Chemistry
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- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology**
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- Mathematics
- Mechanical Engineering
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- Physics
- Robotics
- Sophomore Engineering

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Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Mathematics

Professors Brooks, Broughton, K. Bryan, Butske, S. Carlson, Condori, M. DeVasher, Evans, Finn, Galinaitis, Graves, Grimaldi, Holden, A. Holder, L. Holder, Inlow, Jajcayova, Langley,Lautzenheiser, Leader, Rader, Rickert, Shibberu, and Su.

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Pre: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.
A 5-week fast paced course equivalent to Calculus I, II and III.Taught in the summer only to incoming freshmen. Review of differential calculus.Introduction to integration and the Fundamental Theorem of Calculus.Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

MA 101 Introductory Calculus 5R-0L-2C F (5 weeks)
Covers approximately the first half of MA 111, including analytic geometry in the plane, algebraic and transcendental functions, limits and continuity, and an introduction to differentiation. Entering first-year students will enroll in MA 111 and transfer to MA 101 if continuation of MA 111 is not appropriate.

MA 102 Differential Calculus 5R-0L-3C W Pre: MA 101
Covers approximately the second half of MA 111, including the derivative, geometrical and physical applications of differentiation, and an introduction to integration and Fundamental Theorem of Calculus. Students who do not transfer to MA 101 in the fall quarter, but do not satisfactorily complete all of MA 111, may use their midterm grade in MA 111 for credit and grade in MA 101 and enter MA 102 at the beginning of the winter quarter.

MA 111 Calculus I 5R-0L-5C F
Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

MA 112 Calculus II 5R-0L-5C F,W,S Pre: MA 111 or 102
Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

MA 113 Calculus III 5R-0L-5C F,W,S Pre: MA 112
Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

MA 190 Contemporary Mathematical Problems 2R-0L-2C S co-requisite: MA 113
A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and

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- Mathematics
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applications, famous problems, and outstanding problems of great significance.

MA 221 Differential Equations and Matrix Algebra I 4R-0L-4C F, W, S

Pre: MA 113

First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 222 Differential Equations and Matrix Algebra II 4R-0L-4C F, W, S Pre: MA 221

Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Laplace transforms. Solving small systems of first order linear differential equations by Laplace transforms. Series solutions. Fourier series. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F, W, S Pre: MA 112

This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to simple probability concepts, and random variables (including their linear combinations and expectations). The Central Limit Theorem will be presented. Hypothesis testing and confidence intervals for one mean, one proportion, and one standard deviation/variance will be covered as well as hypothesis testing and confidence intervals for the difference of two means. An introduction to one factor analysis of variance and simple linear regression will be presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 275 Discrete and Combinatorial Algebra I 4R-0L-4C F,WPre: MA 112

An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

MA 323 Geometric Modeling 4R-0L-4C W (even years) Pre: MA113

Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C S Pre: CSSE 220 and MA 222

Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

MA 327 Low Dimensional Topology 4R-0L-4C W, (odd years) Pre: MA 113 or consent of instructor

An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

MA 330 Vector Calculus 4R-0L-4C F Pre: MA 113

Calculus of vector-valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

MA 332 Introduction to Computational Science 4R-0L-4C F Pre: MA222

An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years) Pre: MA221 and programming

experience

Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

MA 336 Boundary Value Problems 4R-0L-4C S Pre: MA 222

Introduction to boundary value problems and partial differential equations. Emphasis on boundary values problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

MA 341 Topics in Mathematical Modeling 4R-0L-4C W Pre: MA 222 or consent of instructor

An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

MA342 Computational Modeling 4R-0L-4C S Pre: MA332

Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

MA 348 Continuous Optimization 4R-0L-4C S (even years) Pre: MA 222

Optimization of nonlinear functions of real variables: algorithms for univariate optimization; Golden section, parabolic interpolation, hybrid methods; Newton's Method and variations for multivariate functions; conjugate gradients and quasi-Newton methods; line search strategies; penalty functions for constrained optimization; modeling and applications of optimization.

MA 351-6 Problem Solving Seminar 1R-0L-1C F, W, S Pre: Consent of instructor

An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

MA 366 Functions of a Real Variable 4R-0L-4C W Pre: MA 275 and MA 113

Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

MA 367 Functions of a Complex Variable 4R-0L-4C S Pre: MA 221

Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

MA 371 Linear Algebra I 4R-0L-4C F,S Pre: MA 221 or consent of instructor

Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. **A student cannot take both MA 371 and MA 373 for credit.**

MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W Pre: MA 221 or consent of instructor

Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. **A student cannot take both MA 371 and MA 373 for credit.**

MA 375 Discrete and Combinatorial Algebra II 4R-0L-4C W,S Pre: MA 275

A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

MA 376 Abstract Algebra 4R-0L-4C S Pre: MA 275

An introduction to modern abstract algebra and algebraic structures. Topics include congruence and modular arithmetic; rings, ideals, and quotient rings; fields, finite fields, and subfields; groups and subgroups;

homomorphisms and isomorphisms. Other topics may also be introduced according to time and student interest.

MA 378 Number Theory 4R-0L-4C S Pre: consent of instructor

Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F, W, S Pre: MA 113

Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C (F) Pre: MA 381

This is an introductory course in statistical data analysis and mathematical statistics.

Topics covered include descriptive statistics, Sampling distributions (including the central Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. **A student cannot take both MA 223 and MA 382 for credit.**

MA 383 Engineering Statistics II 4R-0L-4C F Pre: MA 223 or MA 382

Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Pre: MA 223 or MA 382

Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual's charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as CHE 385.

MA 386 Statistical Programming 4R-0L-4C Pre: previous programming course and either MA 223 or MA 382

Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Pre: MA223 or MA382

A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

MA 423 Topics in Geometry 4R-0L-4C (arranged) Pre: MA371 or MA373 or consent of instructor

An advanced course in geometry. Topics could include from projective geometry, computational geometry, differential geometry, Riemannian geometry, algebraic geometry, Euclidean geometry and non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

MA 431 Calculus of Variations 4R-0L-4C (arranged) Pre: MA 330

Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to "direct methods." Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

MA 433 Numerical Analysis 4R-0L-4C W Pre: MA 222

Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical

integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

MA 434 Topics in Numerical Analysis 4R-0L-4C (arranged) Pre: MA433

An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years) Pre: MA 366

Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green's function.

MA 439 Mathematical Methods of Image Processing 4R-0L-4C F Pre: MA222

Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

MA 444 Deterministic Models in Operations Research 4R-0L-4C W Pre: MA 221 or MA 371/373

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development "from the ground up."

MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years) Pre: MA 223 or MA 381

Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

MA 446 Combinatorial Optimization 4R-0L-4C S (even years) Pre: MA 375

An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

MA 450 Mathematics Seminar 1R-0L-1C F, W, S Pre: consent of instructor

A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

MA 460 Topics in Analysis 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

MA 461 Topics in Topology 4R-0L-4C (arranged) Pre: MA 366 or consent of instructor

Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C (arranged) Pre: MA 366

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C (arranged) Pre: instructor permission

An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Pre: MA 371 or MA 373

Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Pre: CSSE 230 and MA 375

Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Pre: CSSE 230 and MA 375

Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C (arranged) Pre: MA 375

An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Pre: MA 375 or consent of instructor

Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (evenyears) Pre: MA 375 or consent of instructor

An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C(arranged)Pre: MA 378 or MA 375 or consent of the instructor

Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory.A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Pre: CSSE 220 and MA 275

Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C (arranged) Pre:instructor permission

An advanced course in probability or statistics.Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis.May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Pre: MA 382, or MA 381 and consent of instructor

An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Pre: MA 223 or MA 382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Pre: MA

221 and either MA 223 or MA 382

Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Pre: MA 223 or MA 382

Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics, variable credit, Pre: consent of instructor

This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Pre: Senior Standing or permission of the instructor

An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

MA 492 Senior Project I 2C F Pre: Senior Standing or permission of the instructor

MA 493 Senior Project II 2C F, W Pre: MA 492 or permission of the instructor

MA 494 Senior Project III 2C W, S Pre: MA 493

Participation in sponsored projects or problems with a substantial mathematical and/or computational content. Students typically work in teams of at most 3, with appropriate faculty supervision. Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of Senior Project must be completed in a form acceptable to the sponsor and the advisor.

MA 495 Research Project in Mathematics, variable credit, Pre: consent of instructor

An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

MA 496 Senior Thesis I 4C F Pre: Senior Standing or permission of the instructor

MA 497 Senior Thesis II 2C F, W Pre: MA 496 or permission of instructor

MA 498 Senior Thesis III 2C W, S Pre: MA 497

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

Graduate Level Courses

MA 534 Management Science 4R-OL-4C F (even years) Pre: Senior or graduate standing

A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534. **MA 580 Topics in Advanced Probability Theory and Its Applications 4R-OL-4C (arranged) Pre: MA 381**
Advanced topics in probability theory as well as applications that are not offered in the listed courses.

MA 581 Topics in Advanced Statistics 4R-OL-4C (arranged) Pre: MA 223 or MA 381 and consent of instructor

This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

MA 590 Graduate Topics in Mathematics Variable credit Pre: consent of instructor

This course will cover graduate-level topics in mathematics not offered in listed courses.



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ME 123 Computer Applications I 4R-0L-4C W,S Pre: None

Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion (Working Model), presentation software (Powerpoint, HTML), and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S

Selected student design projects. May include testing and/or computer aided design.

ME 201 Thermodynamics I 4R-0L-4C W Pre: MA 112

Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre:

Sophomore class standing

Selected student design projects. May include testing and/or computer aided design.

ME 301 Thermodynamics II 4R-0L-4C F,W Pre: ES 202 or ME 201

Applies property and component background to the analysis of various power and refrigeration cycles. Presents gas and gas-vapor mixtures, psychometric processes, and combustion. Introduces compressible flow.

ME 302 Heat Transfer 4R-0L-4C S,F Pre: MA 222 and ES 202 or CHE 301 or EM 301

Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Pre: ES 202

Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Pre: EM 104

This is an introductory course that examines the interactions between design and manufacturing from the designer’s point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Pre: ME 328

An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Pre: ECE 207, MA 223

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Computer Applications II 1R-3L-2C W,S Pre: ME 123, MA 221 Co: MA 222

Introduction to structured programming and applied numerical methods in scientific computing. The course uses applied problems in engineering and mathematics to introduce numerical methods such as numerical interpolation, finite differencing, integration, root finding, and linear algebraic system solutions. Matlab is taught as a vehicle for solving the problems numerically in a structured high speed environment.

ME 328 Materials Engineering 4R-0L-4C F Pre: CHEM 111 or CHEM 201 or CHEM 105

Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Pre: Permission of instructor

Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in ♦on-the-spot♦ design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Junior class standing

Selected student design projects. May include testing and/or computer aided design.

***ME 401 Foundation of Fluid Mechanics 3R-3L-4C Pre: ES 202 or EM 301, MA 222**

Covers the fundamental concepts of fluid dynamics with an emphasis on physical understanding. Topics include control-volume and differential analyses of fluid motion, similitude, potential flow, vorticity transport, low Reynolds number flow, boundary-layer physics, turbulent transport, and compressible flow. Numerical and experimental methods for solving fluid engineering problem are introduced in a weekly laboratory including wind tunnel, particle image velocimetry, hot wire anemometry, and optical techniques. Other topics may be added or deleted as needed.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective*

***ME 402 Advanced Heat Transfer 4R-0L-4C Pre: ME 302**

This course covers additional topics in conduction, convection and radiation heat transfer as well as an introduction to mass transfer, phase change and numerical methods.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 403 Kinematics of Machinery 4R-0L-4C Pre: ES 204, ME323

This is an introduction to kinematics, the study of the motion of machinery without regard to forces. Students perform both kinematic analysis and kinematic design of planar and spatial mechanisms, cams, and gear trains. Computer programming is used for iterative methods in both analysis and design. A design project is assigned to explore a particular kinematics problem in detail.

***ME 405 Theoretical Aerodynamics 4R-0L-4C F Pre: ES 202**

Introduction to aerodynamics theory. Development of equations of conservation of mass and momentum. Vorticity, induced velocity and irrotational flow. Stream function, velocity potential, Laplace♦s equation and the principle of superposition. Flow about a body, the Kutta-Joukowski Theorem. Concepts of thin airfoil and finite wing theory. Exact solutions to elementary viscous flow problems.

** May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.*

ME 406 Control Systems 3R-3L-4C F Pre: ES 205

Basic principles of feedback control theory. Mathematical modeling and performance analysis of dynamical systems. Includes stability analysis, root locus compensation and design, frequency response analysis. Implementation of control system analysis and design is gained with several laboratory experiences.

ME 407 Power Plants 4R-0L-4C S Pre: ME 301

Steam, cogeneration and combined cycles are studied with the aid of property software. Various components of the cycles are studied in detail. A survey of alternative power sources is presented. Tours of power plants are

taken when available.

ME 408 Renewable Energy 4R-0L-4C Pre: ES 202 or equivalent

Covers renewable energy sources such as solar heating and cooling, wind energy, biomass, and photovoltaic energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate the system. Students will design a system which utilizes a renewable energy source and economically evaluate the system.

ME 409 Air Conditioning 4R-0L-4C F Pre: ES 202 and ME 302 or consent of instructor

Human comfort and the properties of air. Air conditioning in residences, public and industrial buildings using vapor compression and absorption units. Cooling loads, psychrometry, fans, duct sizing and layout, automatic control, and acoustic design considerations.

ME 410 Internal Combustion Engines 4R-0L-4C F Pre: ES 202

Study of spark ignition and compression ignition engines. Influences of engine design features on performance, economy, and air pollution. Influence of the combustion process, carburetion, fuel injection and ignition characteristics on engine operation.

ME 411 Propulsion Systems 4R-0L-4C S Pre: ME 301

Application of basic principles in the study of the performance characteristics of air and space vehicles. Aerodynamics of steady one dimensional isentropic compressible flow. Shock waves, gas turbines, turbojet, turbofan, turboprop, turboshaft, ram jet, rocket, nuclear propulsion and space propulsion systems are discussed and compared.

ME 415 Corrosion and Engineering Materials 4R-0L-4C Pre: ME 328 or CHE 362

Presents fundamentals of metallurgy and corrosion mechanisms in engineering metals. Discusses various classes of corrosion and methods of mitigating corrosion with emphasis on practical situations.

ME 416 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.

***ME 417 Advanced Materials Engineering 4R-0L-4C Pre: ME 328 and EM 203 or EM 204**

Fundamentals of deformation and fracture in metals, polymers, and ceramics with application to design. Emphasis on time-temperature dependence of polymers, brittle behavior of advanced ceramics, and the fracture mechanics approach to design of high strength and critical application materials.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 419 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.

ME 420 Consulting Engineering Seminar 2R-0L-2C S Pre: Junior class standing

Discusses problems in the field of consulting engineering; seminars presented by practicing consulting engineers.

ME 421 Mechanical Engineering Laboratory 0R-6L-2C F,W Pre: ME 321 and RH 330

Introduction to engineering experimentation, centered on an experimental project planned and executed by students. Uncertainty analysis, instrumentation systems, and statistical design of experiments. Emphasis on project on project planning and execution, developing a scope of work, interim deliverables, and reporting engineering results.

***ME 422 Finite Elements for Engineering Applications 4R-1L-4C W Pre: Junior class standing**

Introduces finite element methodology from a strongly theoretical perspective. Emphasizes solving various one-dimensional, transient, non-linear problem statements including heat conduction, beam deflection, convection/diffusion (transport), gas dynamic shocks, and open channel flows. Assesses higher order bases, time stepping procedures, iterative solvers, and finite difference methodologies. Utilizes Matlab for computational experiments.

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 424 Composite Materials and Mechanics 3R-3L-4C Arranged Pre: ES 202

Introduces materials and mechanics of composites with emphasis on high performance polymer matrix composites. Topics include material selection, laminate analysis, manufacturing, joining, and testing. A team design-built-test project is required.

ME 425 Aerospace Engineering Laboratory 1R-3L-2C Pre: ES 202

Introduction to experiment planning and execution. Projects involve wind tunnel testing including measurement of forces and moments and flow visualization. Student organized and executed with direct faculty consultation. Emphasis on written presentation.

ME 426 Turbomachinery 4R-0L-4C Pre: ES 205 and ES 202 or equivalent

Introduces the theory and issues related to the design of axial and radial flow turbines, compressors and pumps. Euler's equation and vector diagrams are used to evaluate energy transfer and efficiency.

***ME 427 Introduction to Computational Fluid Dynamics 3R-3L-4C Pre: ES 202 and ME 323**

Covers the key components of a CFD calculation: mesh generation, numerical algorithm and turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal order of accuracy, dissipation, dispersion, stability and space-time coupling are discussed in detail. Both structured programs and commercial software will be used as vehicles in obtaining a CFD solution.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 430 Mechatronic Systems 3R-3L-4C F,W Pre: ECE 207, ME 323 or consent of instructor

Applications of microprocessors and microcontrollers and digital electronics to the design and utilizations of embedded control systems in smart systems and products. Topics include Boolean logic and algebra, system hardware and software development, and interfacing for mechanical applications.

***ME 435 Robotics Engineering 3R-3L-4C S Pre: ME 430 and Senior class standing**

Interdisciplinary course in engineering systems applied to computer controlled automata. Topics include kinematics, control, operation, sensing, and design as applied to various types of industrial and other robots and programmable manipulators. A related project is required.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 461 Aircraft Design 4R-0L-4C W Pre: ME 305 or consent of instructor

Fundamentals of conceptual aircraft design. Aerodynamic analysis, design constraints based on customer requirements, mission profiles, aircraft sizing, optimization, and presentation of performance capabilities. Oral and written communication emphasized. Design teams. Can be taken in lieu of ME 460, Machine Design or ME 462, Thermal Design.

ME 462 Thermal Design 4R-0L-4C W,S Pre: ES 202 and ME 302

Applications of the thermodynamic, heat transfer, and fluid flow principles to the modeling and design of thermal systems. These systems include pumps, fans, and heat and mass exchangers. A team project which includes the design, construction and testing of a fluid or thermal device or system provides the focus for the course.

ME 470 Engineering System Design 3R-3L-4C F,S Pre: 3rd qtr junior standing

Design of multi-component systems with consideration of societal and economic factors. Useful design techniques (such as modeling, CPM, optimization, probabilistic approaches, etc.) and factors influencing design (such as human factors, products liability, ethics, safety, etc.) are presented and discussed. Laboratory assignments emphasize case studies. (Students completing ME470 may not receive credit for EMGT 461.)

ME 471 Capstone Design I 0R-6L-2C W Pre: ME 470, ME 480

Design projects with industry. Students work in teams with three or four members on design projects furnished from external clients. The emphasis is on creating design solutions, with appropriate analyses, to meet stakeholders' needs. In addition to regular meetings with their faculty advisors, the teams are expected to maintain close and continuous communications with their clients during the quarter. The ten week projects culminate in oral presentations and Interim Written Reports which are submitted to the clients.

ME 472 Capstone Design II 1R-6L-3C S Pre: ME 471

This course is a continuation of ME 471. The student teams continue their design solutions to a general problem furnished by an external client. Continuous and regular communication with the outside clients is expected, as well as with the faculty advisors. During these ten weeks the teams continue refining their solutions, complete the detail design, make oral presentations of the final design, and complete and submit the Final Written Report.

ME 480 Machine Component Design 4R-0L-4C S & F Pre: EM 204

Applications of fundamentals of engineering mechanics in analysis and synthesis of machine components and systems. Special emphases placed on stress/strength analyses and fatigue failures. Design of mechanical components and systems including threaded fasteners, springs, bearings, gears, shafts, clutches, brakes, belts, chains, and couplings.

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of

freshman and sophomore course requirements and approval of adviser and course instructor
Selected projects for student research.

ME 493 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Senior class standing
Selected student design projects. May include testing and/or computer aided design.

ME 497 Special Topics in Mechanical Engineering 4R-0L-4C Arranged
Topics of current interests in mechanical engineering.

Note: Maximum 8 credits total in ME 193, ME 293, ME 393, ME 490, ME 491 and ME 493.

Undergraduate-Graduate Courses

ME 490-491 Directed Research. Hours as assigned. Maximum 4 credits per term. F,W,S Pre: Completion of freshman and sophomore course requirements and approval of adviser and course instructor.

***ME 501 Advanced Thermodynamics 4R-0L-4C F Pre: ME 301 or equivalent**
Study of advanced thermodynamic topics: modeling of transient systems, exergy (availability) analysis, equations of state and thermodynamics relationships for simple, compressible substances.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 502 Topics in Heat Transfer 4R-0L-4C Arranged Pre: ME 302**
Course may be repeated for different heat transfer topics.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 503 Viscous Fluid Flow 4R-0L-4C Pre: ME 401**
Material and spatial descriptions of fluid motion. The Reynolds transport equation. The stress tensor and governing equations for the motion of viscous fluids. Newtonian fluids, the Navier-Stokes equations. Asymptotic solutions including fully developed channel flow, oscillating flat plate, wakes and jets. Introduction to boundary layers and turbulent flow including Reynolds averaging.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 505 Modeling and Simulation of Dynamic Systems 4R-0L-4C Pre: ES 205, MA 222**
Modeling and simulation of engineering components and systems. Emphasis on a unified work-energy approach to modeling physical systems, model formulation using a differential-algebraic form of Lagrange's equation, and the numerical solution of the resulting initial-value problem. Applications are explored using modeling and simulation projects.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 506 Advanced Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**
Physical models for control; system response, analysis and design. Time domain; system response, analysis and design. Frequency domain; state variable representation/description; stability, controllability, observability; linear quadratic regulator, pole-placement, state estimation/observers.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 507 Applied Nonlinear Control Systems 4R-0L-4C Pre: ME 406 or equivalent or consent of instructor**
Analysis and design of controls for inherently nonlinear systems and the use of nonlinear elements in design. Techniques for analysis and design include, stability by Liaquonov, describing functions, phase plane analysis, sliding control, adaptive control and control of multi-input systems.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 510 Gas Dynamics 4R-0L-4C F Pre: ES 202**
Introduction to the dynamics of a compressible flow. Equations of motion for subsonic and supersonic flow. Nozzle flow. Normal and oblique shock waves, Prandtl-Meyer flow. Steady and unsteady, one dimensional gas flow with friction and heat transfer
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..

***ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Pre: ES 205 and ME 323**
Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 512 Light Weight Structures 4R-0L-4C S Pre: MA 222 and EM 203 or EM 204**
Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers

stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 513 Environmental Noise 4R-0L-4C F Pre: Senior class standing**

Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Pre: JR or SR standing

Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.
Students enrolled in EP510, ME516, ECE516, CHE505, BE516 must do project work on a topic selected by the instructor.

***ME 518 Advanced Kinematics 4R-0L-4C S Pre: ME 303**

Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for position, velocity, acceleration, and workspace. The techniques used for the analysis include vector approaches, homogeneous transformations, and dual number techniques.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

ME 519 Advanced MEMS: Modeling and Packaging 3R-3L-4C F Pre: EP410 or equivalent course

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics.
Students enrolled in EP511, ME519, ECE519, CHE519, BE516 must do project work on a topic selected by the instructor.

***ME 520 Computer-Aided Design and Manufacturing (CAD/CAM) 4R-0L-4C W Pre: EM 104 and Senior class standing**

Use and management of computer in engineering for drafting, design management, documentation, and manufacturing. Covers drafting methods and standards, design data management, CNC operations and implementation.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 522 Advanced Finite Element Analysis 4R-1L-4C S Pre: ME 422**

A continuation of ME 422. Includes multi-dimensional extensions of 2-D theory for transient, nonlinear problem statements in engineering. Utilizes Matlab and Ansys for developing and assessing FEA solutions to real world problems via theory developed in ME 422.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 590 Thesis Research F,W,S**

Credits as assigned; however, not more than 12 credits will be applied toward the requirements of an M.S. degree.
* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective.

***ME 597 Selected Topics for Graduate Students. Credits as assigned. Maximum 4 credits per term. F,W,S**

* May be used to satisfy Mechanical Engineering requirement for an advanced technical elective..



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MS 203: Foundations of Tactical Leadership II 2R-3L-2C S Pre: MS 201 and 202 or Instructor Permission

MS203 continues the examination of the challenge of leading tactical teams in the complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations. Cadets develop greater self-awareness as they practice communication and team building skills. Contemporary Operational Environment case studies give insight into the importance and practice of teamwork and tactics in real world scenarios.

MS 206: ROTC Leaders - Training Course

Covering a training period of approximately thirty days, the Department of Military Science ROTC battalion provides travel to and from Fort Knox. Students may attend to access their desire to continue and contract into the ROTC Advanced Course. While in the course, you will meet students from all over the nation while earning \$700 in pay and receive free room and board. You may apply for a two-year Full-tuition scholarship and receive up to \$1200 annually for books and earn a monthly stipend of over \$450 per month for 10 months per year. The Leaders' Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

JUNIOR YEAR Advanced Course

MS 301: Adaptive Team Leadership 3R-3L-4C F Pre: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)

MS 301 challenges cadets to study, practice, and evaluate adaptive leadership skills as they are presented with challenging scenarios related to squad tactical operations. Cadets receive systematic and specific feedback on their leadership attributes and actions. Based on such feedback, as well as their own self-evaluations, cadets continue to develop their leadership and critical thinking abilities. The focus is developing cadets' tactical leadership abilities to enable them to succeed at ROTC's summer Leadership Development and Assessment Course (LDAC).

MS 302: Leadership Under Fire 3R-3L-4C W Pre: MS 301

MS 302 uses increasingly intense situational leadership challenges to build cadet awareness and skills in leading small units. Skills in decision-making, persuading and motivating team members when "under fire" are explored, evaluated, and developed. Aspects of military operations are reviewed as a means of preparing for the ROTC Leader Development and Assessment Course (LDAC). Cadets are expected to apply basic principles of the Law of Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operation orders. Cadets are evaluated on what they know and do as leaders.

MS 303: Leadership under Fire II 3R-3L-4C S Pre: MS 302

MS 303 continues development in decision making, persuading, and motivating team members in operational situations are explored, evaluated and developed. Aspects of military operations are reviewed as a means of preparing for LDAC. Cadets are expected to apply basic principles of Law of the Land Warfare, Army training, and motivation to troop leading procedures. Emphasis is also placed on conducting military briefings and developing proficiency in garrison operations orders. Cadets are evaluated on what they know and do as leaders.

**Overview of LDAC: Leader Development and Assessment Course
Summer Term Only**

LDAC/Warrior Forge is the crucible of the Army ROTC Program. As such, Cadet Command must provide the best professional training and evaluation possible for all cadets. The primary focus at LDAC is to evaluate each cadet's officer potential in a collective environment. The secondary purpose of LDAC is to validate specific skills taught on campus and to impart selective individual and collective common skills. LDAC represents the only opportunity for this command to assemble cadets from disparate schools into an environment with common operational conditions.

SENIOR YEAR- Advanced Course

MS 401: Developing Adaptive Leaders 3R-3L-4C F Pre: MS 303

MS 401 develops cadet proficiency in planning, executing, and assessing complex operations, functioning as a member of a staff, and providing performance feedback to subordinates. Cadets assess risk, make ethical decisions, and lead fellow ROTC cadets. Lessons on military justice and personnel processes prepare cadets to make the transition to Army officers. Cadets analyze, evaluate, and instruct cadets at lower levels. Both their classroom and battalion leadership experiences are designed to prepare cadets for their first unit of assignment. They identify responsibilities of key staff, coordinate staff roles, and use situational opportunities to teach, train,

and develop subordinates.

MSL 402: Leadership in a Complex World 3R-3L-4C W Pre: MS 401

MS 402 explores the dynamics of leading in the complex situations of current military operations in the COE. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. They also explore aspects of interacting with nongovernmental organizations, civilians on the battlefield, and host nation support. The course places significant emphasis on preparing cadets for their first unit of assignment. It uses case studies, scenarios, and "What Now, Lieutenant?" exercises to prepare cadets to face the complex ethical and practical demands of leading as commissioned officers in the United States Army.

MS 403: Leadership in a Complex World II 3R-3L-4C S Pre: MS 402

MS 403 continues the exploration of the dynamics of leading in the complex situations of current military operations from MS 402. Cadets examine differences in customs and courtesies, military law, principles of war, and rules of engagement in the face of international terrorism. Aspects of interacting with non-government organizations, civilians on the battlefield, and host nation support are examined and evaluated. Significant emphasis is placed on preparing cadets for their first unit of assignment as Second Lieutenants.

Academic Electives

In order to fulfill commissioning requirements, cadets in the Military Science program must take and successfully complete one college undergraduate course to satisfy the Professional Military Education (PME) requirement for American Military History. This should be taken during the course of the student's four years of academic studies and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.



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Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

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Multi-Disciplinary Studies

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Pre: Permission of instructor
Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. *This course may not be used as credit toward any degree program. This course is given Pass/Fail.*

- Aerospace Studies (Air Force ROTC)
- Applied Biology & Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Science & Software Engineering
- Electrical & Computer Engineering
- Engineering Management
- Engineering Mechanics
- Engineering Physics
- Geology
- Humanities and Social Sciences
- Mathematics
- Mechanical Engineering
- Military Science (Army ROTC)
- Multi-Disciplinary Studies
- Optical Engineering
- Physics
- Robotics
- Sophomore Engineering

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Graduate Studies

Optical Engineering

Professors: Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, Kirtley, Lepkowicz, Letfullin, McInerney, Moloney, Siahmakoun, Syed, Wagner, and Western.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

OE 171 Photography and Holography 2R-OL-2C F
Introduce students to basic knowledge of optics, principles and operation of a camera, shutters, films, and film development, color photography. Basic understanding of interference of waves, concept of holography, properties of various holograms, application of holography, and each student makes an individual hologram that can be seen in sunlight.

OE 172 Optics in Technology 2R-OL-2C S
Introduction to the properties of lasers; types of lasers; characteristics of optical fibers, optical communication, applications of lasers and fibers in industry, medicine and commercial products; fundamentals of holography, applications in art and industry.

OE 280 Paraxial Optics 3.5R-1.5L-4C W Pre: PH 113
First order geometrical optics including image formation, y-nu ray tracing, cardinal points, stops and apertures, matrix methods and an introduction to optical instruments. Introduction to computer-aided analysis.

OE 290 Directed Research Credit arranged Pre: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 295 Optical Systems 3.5R-1.5L-4C S Pre: PH 113 and MA 221
Components of optical systems; introduction to lasers light and Gaussian beams; optical fibers; fiber optic systems; radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; noise in detectors; CCD arrays, optical instruments.

OE 360 Optical Materials and Opto-Mechanics 4R-OL-4C F Pre: OE 295
Optical properties of materials, optical coatings, principles of opto-mechanical design, fold mirrors and prisms, tolerancing, specifications of optical components, lens and mirror mounting, kinematics systems, precision adjustments and control.

OE 392 Wave Optics & Coherence 4R-OL-4C Arranged Pre: PH 292, MA 222
Propagation of light, Fresnel equations; Fraunhofer and Fresnel diffraction; coherence; Fourier transforms, convolution and correlation; optical transfer function (OTC), modulation transfer function (MTF); speckles; holography, moire.

OE 393 Fiber Optics and Applications 3R-3L-4C W Pre: OE 295, PH 316 or ECE 341 or consent of instructor
Basic dielectric waveguide equations; wave optics and ray optics; step-index and graded-index fibers; single mode and multi-mode fibers; mode cutoff conditions; numerical aperture; fabrication of optical fibers; fiber measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

components and systems.

OE 395 Optical Instrumentation 3R-3L-4C Arranged Pre: OE 280 and PH 292

Radiometry and photometry; optoelectronics; LEDs; optical sources; detectors; signal conditioning and noise; CCD arrays; optical instruments; color; selected experiments on the application of optical instruments.

OE415 Optical Engineering Design I 2R-6L-4C S Pre: OE 295 Coreq: RH330 or consent of the instructor

Principles of design. Codes of ethics appropriate to optical engineers. Case studies related to optical engineering professional practice, teamwork, contemporary issues, patents and intellectual property. Team oriented design project work on selected topics in optical engineering. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints.

OE416 Optical Engineering Design II 2R-6L-4C F Pre: OE 415

Design project, system-level design and detail design. Construction of a prototype product. Product development economics, costs and market research. Testing optical components and systems, electronic systems, optical measurement tools, mechanical measurements, opto-mechanics, and opto-electronics.

OE417 Optical Engineering Design III 2R-6L-4C W Pre: OE416

Continuation of OE416 design project. Delivery of a functional prototype product. Complete product development documentation including a technical report, design documents, product design specification, drawings, acceptance test document, project plan. Oral presentation.

OE 435 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 222, and SR/GR standing

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications. Same as BE 435.

OE 450 Laser Systems and Applications 3R-3L-4C S Pre: PH 292 and MA 222 or JR standing or consent of instructor

Laser safety; Gaussian beam propagation; cavity design; longitudinal and transverse modes; stimulated emission; population inversion; rate equations; gain and threshold; Q-switching and mode-locking; types of laser systems; laser applications in communication; medicine, military, and industry.

OE 470 Special Topics in Optical Engineering 2-4 Credits Pre: Consent of instructor

Lectures on special topics in optics.

OE 480 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 Coreq: OE 360 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, y-y bar diagrams as a design tool, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Introduction to computer-aided design, design of optical systems including camera lenses, mirror systems and catadioptric systems.

OE 485 Electro-Optics and Applications 3R-3L-4C W Pre: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, electro-optic effect in liquid crystals, photorefractive effect, acousto-optic effect and modulators, second-harmonic generation, optical phase-conjugation and applications.

OE 490 Directed Research Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3R-3L-4C F Pre: OE393, ECE310 or graduate standing or consent of the instructor

Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Soliton propagation. Relevant laboratories

OE 495 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); review of interference and coherence; fringe visibility; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis or initiation of research to be completed in an MSOE degree at Rose-Hulman.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

OE 520 Principles of Optics 2R-0L-2C F Pre: OE 295, PH 292, PH 316 or SR/GR standing or consent of instructor

Classical optics; exact ray tracing; aberrations, interference, polarization, spatial and temporal coherence; lasers and Gaussian beam propagation; diffraction; optical sources and detectors; selected applications of optics.

OE 535/BE 535 Biomedical Optics 4R-0L-4C W Pre: PH 113, MA 222 or SR/GR standing or consent of instructor

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with tissues, laser diagnostics and therapy, laser surgery, endoscopy and applications; fiber optics; fiber optic biosensors; microscopes; optics-based clinical applications. For graduate credit, students must do additional project work on a topic selected by the instructor.

OE 570 Special Topics in Optics 2 or 4C F,W,S Pre: OE 295, PH 292, and PH 316

Lectures on special topics in optics such as: optical materials, optics of thin films and infrared optics.

OE 580 Lens Design and Aberrations 4R-0L-4C F Pre: OE 280 or SR/GR standing or consent of instructor

Chromatic and third order aberrations, exact ray tracing, y y bar diagrams as a design tool, methods for reducing aberrations in initial designs, optimization. Design of simple lens systems. Introduction to computer aided design, design of optical systems including camera lenses, mirror systems and catadioptric systems. For graduate credit, students must do additional project work on a topic selected by the instructor.

OE 585 Electro Optics and Applications 3R-3L-4C W Pre: PH 292 and PH 316 or SR/GR standing or consent of instructor

Optical wave propagation in anisotropic media; normal surface, birefringence, index ellipsoid, optical activity, Faraday rotation, Pockels and Kerr effects, electro-optic modulators, electro-optic effect in liquid crystals, photorefractive effect, acousto-optic effect and modulators, second-harmonic generation, optical phase-conjugation and applications. For graduate credit, students must do additional project work on a topic selected by the instructor.

OE 592 Fourier Optics and Applications 3R-3L-4C F Pre: SR/GR standing or consent of instructor

Two-dimensional linear systems; diffraction theory (Fresnel & Fraunhofer); imaging properties of lenses; frequency analysis of optical imaging systems; spatial filtering; optical information processing; Vander-Lugt filters; wavefront reconstruction; holography; optical computing.

OE 593 Fundamentals of Optical Fiber Communications 3R-3L-4C S

Pre: OE393 or graduate standing or consent of the instructor

Evolution of fiber optics links and networks: information rate, evaluation of fiber optic systems, optical fiber transmission link. Digital transmission systems: point-to-point links, line coding, error correction. Analog systems: links, dynamic range, noise figure, bandwidth, carrier-to-noise, multi-channel transmission, cross talk. WDM concepts: operational principles, passive components, system considerations. Optical networks: network topologies, performance of linear bus, performance of star architecture, SONET, WDM networks, wavelength-routed networks, optical CDMA, ultra high capacity WDM networks, bit-interleaved optical TDM, time-slotted optical TDM.

Students enrolled in OE593 must do project work on a topic selected by the instructor.

OE 594 Guided-Wave Optics 3R-3L-4C S Pre: OE 485 or SR/GR standing or consent of instructor

Theory of optical waveguides; waveguide modes; fabrication techniques; input and output coupling techniques; waveguide losses; waveguide gratings; electro-optic modulators; integrated optical detectors; applications of integrated optics.

OE 595 Optical Metrology 3R-3L-4C F Pre: PH 292 or SR/GR standing or consent of instructor and Co-

Req OE 480

Optical testing: geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann); review of interference and coherence; fringe visibility; conventional interferometers (Newton, Fizeau, Twyman-Green and shearing); fringe localization; phase shifting, holographic, Moire, photoelastic and speckle interferometry; emerging optical methods. Students must do additional project work on a topic selected by the instructor.

OE 599 Thesis Research

Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.



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PH 270 Special Topics in Physics Credit arranged Pre: Consent of instructor

Lectures on special topics in physics. Maximum of 4 credits per term.

PH 290 Directed Research Credit arranged Pre: Consent of instructor

Research for freshmen and sophomore students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

PH 292 Physical Optics 3.5R-1.5L-4C F Pre: PH 113

Electromagnetic waves; interference; optical interferometry; coherence; polarized light; Jones vec-tors/matrices; production of polarized light; birefringence, Fraunhofer diffraction, diffraction gratings.

PH 302 Biophysics 4R-0L-4C W Pre: PH 113 or consent of instructor

Biological examples of the interaction of radiation and matter; medical uses of x-rays, nuclear medicine, magnetic resonance imaging, and current applications in biophysics.

PH 310 Introduction to Special Relativity 2R-0L-2C F Pre: PH 113 or consent of instructor

Experimental background of the special theory of relativity, the structure of the theory and its consequences in measurements involving space, time and motion. Relativistic mechanics, relativity and electromagnetism, and applications in modern physics.

PH 314 Theoretical Mechanics I 4R-0L-4C S, Arranged Pre: PH 111, PH 235, MA 222

Statics and dynamics of particles and systems of particles, including rigid bodies. Conservation of energy, linear and angular momentum. Central forces. Lagrangian and Hamiltonian equations of motion. Vibrations.

PH 315 Theoretical Mechanics II 4R-0L-4C W, Arranged Pre: PH 314

Statics and dynamics of rigid bodies. Lagrangian treatment of rigid body dynamics. Euler method of rigid body dynamics. Small oscillations about positions of equilibrium and about steady motion. Statics and dynamics of deformable bodies. Computational analysis of mechanical systems.

PH 316 Electric and Magnetic Fields 4R-0L-4C F Pre: PH 113, MA 222

Maxwell's equations in integral and point form, vector calculus; electric field and potential, electric fields in matter, boundary conditions; the magnetic field.

PH 317 Electromagnetism 4R-0L-4C W Pre: PH 316

Further methods in electrostatics, Poisson's equation; magnetostatics, the vector potential; electromagnetic induction; magnetic properties of matter; further applications of Maxwell's equations, properties of electromagnetic radiation.

PH 322 Celestial Mechanics 4R-0L-4C S Pre: PH 112 or PH 265

Dynamics of point masses; the two-body problem; the restricted three-body problem; orbital position as a function of time; orbits in three dimensions; preliminary orbit determination; orbital maneuvers; interplanetary trajectories.

PH 325 Advanced Physics Laboratory I 2R-6L-4C S Pre: PH 255 or PH 265

Introduction to the methods of experimental physics; topics may include error analysis, component fabrication, transducers, ac circuits, operational amplifiers, electrical signal conditioning, and automated data acquisition.

PH 327 Thermodynamics and Statistical Mechanics 4R-0L-4C S Pre: PH 235 or consent of instructor

First, second, and third laws of thermodynamics. Ideal gases, real gases, liquids, solids, change of phase. The Joule-Thompson effect, adiabatic demagnetization. Kinetic theory of gases, classical and quantum statistical mechanics.

PH 330 Material Failure 3R-3L-4C W Pre: PH 113

Physical principles of instrumentation used for material failure analysis, including light microscopy, electron microscopy, and spectroscopy. Laboratory includes experiments and case studies using these instruments.

PH 401 Introduction to Quantum Mechanics 4R-0L-4C W Pre: PH 255, or PH 113 and PH 265

Review of wave-particle experiments, atomic model, Bohr theory, deBroglie's hypothesis. Uncertainty principle, Schroedinger equation, quantum mechanical operators and stationary states, quantization and role of angular momentum.

PH 402 Introduction to Atomic Physics 4R-0L-4C S (odd years) Pre: PH 401

Solutions of Schroedinger equation, perturbation theory, applications to one electron system. Quantum numbers, spin and magnetic moments, multi-electron systems including LS coupling. Zeeman effect, transition rates, hyperfine structure, X-rays.

PH 404 Acoustics 4R-0L-4C W (odd years) Pre: PH 113, and MA 222

Harmonic motion, waves on strings, membranes, eigenfunctions and eigenvalues; waves in rods and fluids; behavior of waves at interfaces; radiation from vibrating piston; resonators, absorption.

PH 405 Semiconductor Materials and Applications 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films.

PH 407 Solid State Physics 4R-0L-4C S (even years) Pre: PH 255 or PH 265

Selected topics in the field are discussed in detail; e.g., crystal structures, lattice vibrations and electronic band structure; electrical, optical and thermal properties of solids and semi-conductors; and the properties of materials at very low temperatures.

PH 425 Advanced Physics Laboratory II 0R-8L-4C W Pre: PH 325

Selected experiments in various areas of physics, with primary emphasis on nuclear physics and a significant independent student project

PH 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Pre: MA 222, and JR/SR or Graduate standing

Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Integral laboratory.

PH 440 X-rays and Crystalline Materials 2R-6L-4C S (even years) Pre: PH 255 or PH 265

X-ray emission, absorption, fluorescence, and diffraction. Methods of analyzing crystalline solid materials. Applications in solid-state physics, materials science, chemistry, metallurgy, and biology.

PH 460 Directed Study Credit arranged Pre: Consent of instructor

Permits study in an area of physics not available in regular course offerings. Maximum of 4 credits per term.

PH 470 Special Topics in Physics 2-4 Credits Pre: Consent of instructor

Lectures on special topics in physics.

PH 480 Seminar 0C Arranged

Lectures by staff, students, and outside speakers on topics of special interest.

PH 490 Directed Research Credit arranged Pre: Consent of instructor

Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH 290 and PH 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2C F,W,S Pre: Consent of PHOE faculty

Literature search, research proposal preparation, and laboratory project work. This sequence is designed to result in a completed senior thesis.

Graduate Courses

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Pre: PH 113 or PH 255 or PH 265

Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged

Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged

Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Pre: PH 404

Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Pre: CSSE 220 or ME 323 or ECE 380 or consent of instructor; MA 221

Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Pre: SR/GR standing

Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.



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Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Robotics

ROBO 410 Robotics Capstone Design I 1R-6L-4C F
Pre for EE or CPE: ECE 362, and a co-requisite ME 430
Pre for ME: ME senior class standing, and co-requisites of ME 430 and ME 470
Pre for CS or SE: RH 330 and CSSE 374, and a co-requisite ME 430

ROBO 420 Robotics Capstone Design II 1R-6L-4C W
Pre: ROBO 410

ROBO 430 Robotics Capstone Design III 1R-6L-4C S
Pre: ROBO 420

Description: Interdisciplinary group robotics engineering project. This requires the carrying out, from inception to completion, of a robotics-related system development for an approved client. The focus for students from each major is on design appropriate to that major related to robotics. Teamwork activities are expected to involve coordination of multidisciplinary aspects of the project, team planning, leading, and reviewing of project progress versus risks. Engineering practices related to design include requirements and constraint analysis and management, design creation and documentation, prototyping, system construction and testing, following of engineering standards, and management of intellectual property. Technical completion and delivery to the client is expected.

Aerospace Studies (Air Force ROTC)

Applied Biology & Biomedical Engineering

Chemical Engineering

Chemistry

Civil Engineering

Computer Science & Software Engineering

Electrical & Computer Engineering

Engineering Management

Engineering Mechanics

Engineering Physics

Geology

Humanities and Social Sciences

Mathematics

Mechanical Engineering

Military Science (Army ROTC)

Multi-Disciplinary Studies

Optical Engineering

Physics

Robotics

Sophomore Engineering

R

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Information For

Prospective Students

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Community Members

Industry Partners

Trustees

Parents

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INSTITUTE OF TECHNOLOGY

Intranet

Contact

About

Admissions

Academics

Student Life

News

Calendars

Alumni

Athletics

Offices and Services

Course Descriptions

Programs of Study

Course Descriptions

Minors

Special Programs

Advanced Placement

Graduate Studies

CATALOG HOME

Sophomore Engineering

Curriculum Structure

The Rose-Hulman / Foundation Coalition Sophomore Engineering Curriculum consists of eight courses (30 credit hours) taken over the three quarters of the sophomore year. As shown below the courses are listed as either mathematics (MA) or engineering science (ES) courses:

FALL QUARTER 12 Credit

Hours MA 221

- Differential Equations & Matrix Algebra I (4)
- ES 201 Conservation & Accounting Principles (4)
- ES 203 Electrical Systems (4)

WINTER QUARTER 10 Credit

Hours MA 222

- Differential Equations & Matrix Algebra II (4)
- ES 202 Fluid & Thermal Systems (3)
- ES 204 Mechanical Systems (3)

SPRING QUARTER

8 Credit Hours MA 223

- Statistics for Engineers (4)
- ES 205 Analysis & Design of Engineering Systems (4)

TOTAL 30 Credit Hours

Curriculum Goals

This set of courses has been designed so that students who participate in this program should

- develop a strong background in engineering science,
- develop an understanding of modeling,
- be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
- continue to develop effective communication skills,
- be proficient in applying standard statistical procedures and quality control concepts,
- develop a strong background in mathematics,
- be encouraged to be inquisitive and self-motivated learners,
- develop an appreciation for engineering as a profession and begin to develop an identity as an engineer,
- be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
- be able to apply computer tools appropriately,
- be comfortable working with ambiguity,

Aerospace Studies (Air Force ROTC)
Applied Biology & Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Military Science (Army ROTC)
Multi-Disciplinary Studies
Optical Engineering
Physics
Robotics
Sophomore Engineering

- be familiar with the overall design process,
- be able to locate and retrieve both technical and non-technical information,
- be introduced to safe and effective use of instruments,
- appreciate the role of creativity in engineering,
- develop a recognition of the benefits of the new curriculum, and
- be encouraged to have fun learning.

Each course in the curriculum has been developed around a set of course goals and objectives that support these seventeen curriculum goals.

ES 201 Conservation & Accounting Principles 4R-0L-4C F,W Pre: MA 113, PH 111 Co: MA 221

A common framework for engineering analysis is developed using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Conservation equations for mass, charge, momentum and energy, and an entropy accounting equation are developed. Applications taken from all engineering disciplines stress constructing solutions from basic principles.

ES 202 Fluid & Thermal Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better

Conservation and accounting equations applied to fluid and thermal systems. Fluid and thermodynamic properties of pure substances. Open and closed systems hydrostatics. Dimensional analysis. Mechanical energy balance and pipe flow. Lift and drag.

ES 203 Electrical Systems; 3R-3L-4C; F,W,S; Pre: MA 113, PH 113

Circuit elements, Kirchhoff's laws, equivalent circuits, voltage and current dividers, and analysis techniques for both DC and the phasor domain. AC circuits and power. Operational amplifiers. Integral laboratory.

ES 204 Mechanical Systems 2 2/3R-1L-3C W,S Pre: ES 201 with a grade of C or better Co: ES 202

Conservation and accounting equations applied to mechanical systems. Kinematics and kinetics of particles in space and of rigid bodies in plane motion.

ES 205 Analysis & Design of Engineering Systems 3R-3L-4C S,F Pre: ES 202, ES 203 with a grade of C or better, ES 204, MA 222

Conservation and accounting principles are used to model engineering systems comprising mechanical, electrical, fluid, and thermal elements. Dynamic behavior and performance criteria are characterized in the time and frequency domains. Topics include block diagrams, deriving and solving differential equations of motion, experimental parameter identification and model validation, teaming, and reporting engineering results.



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Programs of Study

Programs of Study	Special Programs
Course Descriptions	Advanced Placement
Minors	Graduate Studies

CATALOG HOME

Entrepreneurship Minor

Increasing globalization and the need for rapid implementation of innovations mean that that 21st Century engineers and scientists need to think like entrepreneurs. Everyone does not have to start a technology based business, but understanding the requirements of technology commercialization needs to be part scientific and technical thinking.

The Engineering Management Program has new programs in entrepreneurship for everyone to consider. These are intended to provide the basic tools for making new technology commercially successful.

The requirements of the undergraduate minor are 20 credits of the following:

- EMGT 427 Project Management
 - SL 350 Managerial Accounting
 - VA 454 Financial Economics
 - VA 453 The Entrepreneur
 - VA 498 Technology Management & Forecasting
- or
- EMGT 423 Intro to Marketing for Technical Products

Note: Three VA courses mean that 10 courses will be required to meet graduation requirements.

Up to 12 credits of EMGT 461, 462 and 463 may be substituted for the classes above. Other substitutions may be made with the approval of the head of the engineering management department. No more than one course may be transferred in to count toward the minor.

Participation in an entrepreneurial senior design experience approved by the head of the Engineering Management Department. This may be a part of the student's departmental design course, as well as participation in the Multidisciplinary, Entrepreneurial Design sequence



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