Course Catalog 2012-2013

Programs of Study
Course Descriptions
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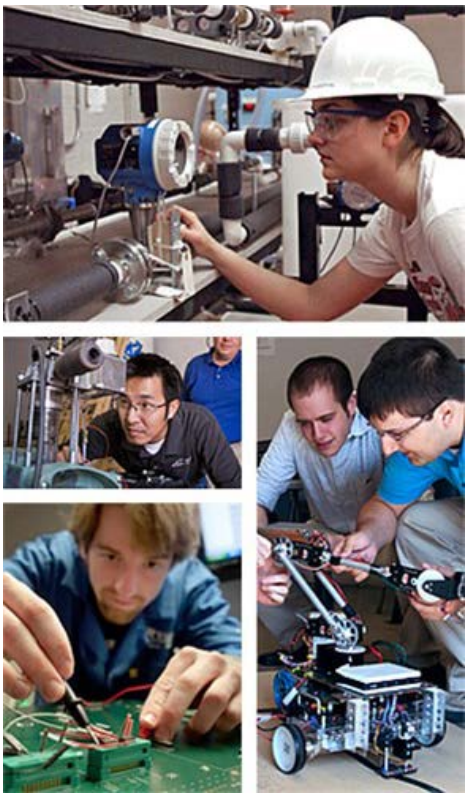
CATALOG HOME

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
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.

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.

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Course Descriptions

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

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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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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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. 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
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 thre 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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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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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 & Molecular Genetics	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		*Credit*		Total	16
AB 120	Comparative Anatomy & Physiology	4	*Winter Term*		*Credit*
CHEM 113	General Chemistry II	4	AB 220	Prokaryotic Cell & Molecular Biology	4
MA 112	Calculus II	5	CHEM 252	Organic Chemistry II	3
BE 100	Problem Solving in the Biological Sciences and Engineering	4	CHEM 252L	Organic Chemistry II Lab	1
	Total	17	PH 112	Physics II	4
Spring Term		*Credit*	RH 330	Technical and Professional Communication	4
AB 130	Evolution and Diversity	4		Total	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	Biochemisty	4
HSS	Elective	4
AB 399	Practice of Science	4
	Total	16
Winter Term		*Credit*
AB 330	Evolutionary Biology	4
AB 496	Senior Thesis Research I	2
AB	Elective	4
HSS	Elective	4
	Total	14
Spring Term		*Credit*
AB 310	Plant Structure & Function	4
AB 497	Senior Thesis Research II	4
SV 304	Bioethics	4
HSS	Elective	4
	Total	16

Senior Year

Fall Term		*Credit*
AB 498	Senior Thesis Research III	4
	Science/Technical Elective	4
HSS	Elective	4
	Free Elective	4
	Total	16
Winter Term		*Credit*
AB 499	Senior Thesis Research IV	2
	Science/Technical Elective	4
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
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

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
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	Evolitionary 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	
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 230	Introduction to Organic Chemistry and Biochemistry
or	
CHEM 251	Organic Chemistry I
and	
CHEM 252	Organic Chemistry II
CHEM 330	Biochemistry
CHEM 430 with CHEM 433	Advanced Biochemistry Biochemistry Laboratory

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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
AB 110	Cell Structure & Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
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
	or	
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
AB 210	Mendelian & Molecular Genetics	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 Undergradute Research	4
MA 381	Introduction to Probability with Applications to Statistics	4
AB 220	Prokaryotic Cell & Molecular Biology	4
	Total	16 or 17
Spring Term		*Credit*

Applied Biology
Biochemistry
Biomedical Engineering
Chemical Engineering
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Mathematics
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Junior Year

Fall Term		*Credit*
CHEM 326	Bioanalytical Chemistry	4
CHEM 330	Biochemistry I	4
CHEM 361	**Physical Chemistry I	4
HSS	Elective	4
	Total	16

Winter Term		*Credit*
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

Spring Term		*Credit*
CHEM 363	Quantum Chemistry & Molecular Spectroscopy	4
CHEM 430	Advanced Biochemistry	4
CHEM 433	Biochemistry Lab	1
HSS	Elective	4
CHEM 490#	Research	1
	Total	14

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	4
AB 230	Eukaryotic Cell & Mol. Biology	4
HSS	Elective	4
	Total	16 or 17

Senior Year

Fall Term		*Credit*
CHEM 441	Inorganic Chemistry I	4
CHEM 401	Chemical Communication II	1
CHEM 490	Chemistry Research	1
	##Advanced Chemistry or Biochemistry Elective	4
	Advanced Biology Elective	4
	Free Elective	4
	Total	18

Winter Term		*Credit*
CHEM 402	Chemical Communication III	1
CHEM 490	Chemistry Research	1
HSS	Elective	4
	##Advanced Biology, Chemistry, Biochem	4
	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
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12

Summary of minimum graduation requirements:

Course or areas	Required	Elective	Total

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**

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**

*CHEM 105 and CHEM 107 can be substituted for CHEM11You 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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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
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Additional Programs of Study

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Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
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- 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*
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
	Total	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
	Total	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
	Total	17

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
AB 130	Evolution and Diversity	4
ES 205	Analysis & Design of Engineering Systems	4
MA 223	Engineering Statistics	4
	Total	16

Junior Year

Fall Term		*Credit*
HSS	Elective	4
AB 205	Cellular Physiology	4
RH 330	Technical and Professional	4

Senior Year

Fall Term		*Credit*
BE 410	Biomedical Engineering Design I	4
HSS	Elective	4

HSS	Communication or 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	Elective or	4
RH 330	Technical and Professional Communication	
	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

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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Programs of Study

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

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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

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

	Total	14
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 (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
HSS	Elective	4
	Total	15

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 325	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 (A1 Schedule)

Fall Term		*Credit*
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
Winter Term		*Credit*
CHE 413	Chemical Eng. Lab III	4
CHE 417	Design II	4
CHE 440	Process Control	4
HSS	Elective	4

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	16
Spring Term		*Credit*
CHE 418	Design III	2
HSS	Elective	4
HSS	Elective	4
	Elective(Approved)	4
	Elective(CHE)	4
	Total	18
	Total credits required:	**194**

	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 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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Programs of Study

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*
CHEM 111*	General Chemistry	4
MA 111	Calculus I	5
AB 110**	Cell Structure and Function	4
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
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
	or	
HSS	Elective	
	Total	17

Spring Term		*Credit*
CHEM 115	General Chemistry III	4
MA 113	Calculus III	5
HSS	Elective	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
	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	17

Junior Year

Fall Term		*Credit*
CHEM 326	Bioanalytical Chemistry	4
CHEM 361	***Physical Chemistry I	4
CHEM 330	Biochemistry I	4
HSS	Elective	4
	Total	16
Winter Term		*Credit*
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
Spring Term		*Credit*
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

	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	Elective	4
	Free Elective	4
	Total	16 or 17

Senior Year

Fall Term		*Credit*
CHEM 441	Inorganic Chemistry I	4
CHEM 401	Chemical Communications II	1
CHEM 490	Research	1
	Chemistry Elective	4
	Free Elective	4
	Total	14
Winter Term		*Credit*
CHEM 442	Inorganic Chemistry II	4
CHEM 402	Chemical Communications III	1
CHEM 490	Research	1
HSS	Elective	4
	Chemistry Elective (400-level)###	4
	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
General Chemistry	111, 113, 115	12

Summary of minimum graduation requirements:

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 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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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 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)	4
	Elective(HSS)		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
	Elective(HSS)		*Spring Term*		*Credit*
CE 110	Computer Applications and GIS	4	MA 223	Statistics for Engineers	4
	Total	17	EM 301	Fluid Mechanics	4
Spring Term		*Credit*	CE 250	Sustainable Civil Engineering Design	2
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 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
	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

Advisor:
Dr. Michael A. Robinson,
Department of Civil Engineering
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Programs of Study

Programs of Study
Course Descriptions
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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 Year**	
Fall Term		*Credit*	*Fall Term*	*Credit*
PH 111	Physics 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

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 130	Introduction to Logic Design	4
CSSE 220	Object-Oriented Software Development	4
	Total	17

MA 211	Differential Equations	4
CSSE 232	Computer Architecture I	4
ECE 203	DC Circuits	4
CHEM 111	General Chemistry I	4
	Total	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	4
	Total	16
Spring Term		*Credit*
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 332	Computer Architecture II	4
ECE 205	Dynamical Systems	4
HSS	Elective	4
	Total	16

Junior Year

Fall Term		*Credit*
MA 275	Discrete & Combinational Algebra I	4
ECE 250	Electronic Device Modeling	4
ECE 300	Continuous-Time Signals Systems	4
RH 330	Technical and Professional Communication	4
	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 Elecromagnetic Compatibility	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 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
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	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
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

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
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 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

Course Number	Course Title	Credits
ECE203 Required	**DC Circuits**	**4**
ECE204 Required	**AC Circuits**	**4**
ECE205	Dynamical Systems	4
ECE300	Continuous-Time Signals Systems	4
ECE380	Discrete-Time Signals and 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 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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Programs of Study

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 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			
RH 131	Rhetoric and Composition	4	MA 275	Discrete & Combinatorial Algebra I	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
Spring Term		*Credit*
CSSE 132	Introduction to Computer Systems	4
MA 113	Calculus III	5
HSS	Elective	4
Science	Elective	4
	Total	17

Junior Year

Fall Term		*Credit*
CSSE 371	Software Requirements Engineering	4
CSSE/MA 473	Design and Analysis of Algorithms	4
CSSE	Elective	4
HSS	Elective	4
	Total	16
Winter Term		*Credit*
CSSE 332	Operating Systems	4
CSSE 374	Software Design	4
CSSE/MA 474	Theory of Computation	4
HSS	Elective	4
	Total	16
Spring Term		*Credit*
CSSE	Elective	4
	Technical Elective	4
Free	Elective	4
Free	Elective	4
	Total	16
	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
HSS	Elective	4
	Total	16
Spring Term		*Credit*
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

Senior Year

Fall Term		*Credit*
CSSE 487	Senior Research Project I	4
	or	
CSSE 497	Senior Project I	
	or	
CSSE 494	Senior Thesis I	
CSSE	Elective	4
HSS	Elective	4
Free	Elective	4
	Total	16
Winter Term		*Credit*
CSSE 488	Senior Research Project II	4
	or	
CSSE 498	Senior Project II	
	or	
CSSE 495	Senior Thesis II	
CSSE	Elective	4
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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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	
HSS	Elective	
	Physical or Life Science	4
	Total	14
Winter Term		*Credit*
MA 112	Calculus II	5
CSSE 120	Introduction to Software Development	4
	Physical or Life Science	4
RH 131	Rhetoric and Composition	4
	or	
HSS	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 Systems of Differential Equations	4
	Economics Elective	4
	*HSS Elective	4
	Physical or Life Science	4
	Total	16
Spring Term		*Credit*
MA 381	Introduction to Probability with Applications to Statistics	4
	or	

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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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 Year**		
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)
Computational Science Major (CPLS) (Second Major Only)
International Studies Major (IS) (Second Major Only)
Military
Pre-Professional Programs

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
ECE 130	Introduction to Logic Design	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
HSS	Elective	4
CSSE 120	Introduction to Software Development	4
	Total	17

CHEM 111	General Chemistry I	4
ECE 203	DC Circuits	4
ECE 230	Introduction to Microcontrollers	4
	Total	16
Winter Term		*Credit*
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Math/Science Elective	4
ECE 204	AC Circuits	4
HSS	Elective	4
	Total	16
Spring Term		*Credit*
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 205	Dynamical Systems	4
ECE 370	Power & Energy Systems	4
	or	
ECE 371	Sustainable Energy Systems	
HSS	Elective	4
	Total	16

Junior Year

Fall Term		*Credit*
ECE 300	Continuous-Time Signals Systems	4
ECE 250	Electronic Device Modeling	4
ECE 340	Electromagnetic Fields	4
RH 330	Technical and Professional Communication	4
	Total	16
Winter Term		*Credit*
ECE 380	Discrete-Time Signals and Systems	4
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 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
ECE203 Required	**DC Circuits**	**4**
ECE204 Required	**AC Circuits**	**4**
ECE205	Dynamical Systems	4
ECE300	Continuous-Time Signals Systems	4
ECE380	Discrete-Time Signals and 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 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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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

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		
Fall Term		*Credit*
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	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
CSSE 120	Introduction to Software Development	4
ME 123	or Computer Applications I	
	Total	17
Spring Term		*Credit*
PH 113	Physics III	4
MA 113	Calculus III	5
CHEM 113	General Chemistry II	4
OE 172	Optics in Technology*	2
EM 103	Introduction to Design**	2
	Total	17*

Sophomore Year		
Fall Term		*Credit*
ES 201	Conservation and Accounting Principles	4
PH 235	Many Particle Physics	4
MA 211	Differential Equations	4
PH 292	Physical Optics	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
ES 202	Fluid & Thermal Systems	3
	Total	15
Spring Term		*Credit*
HSS	Elective	4
OE 295	Optical Systems	4
SV 151	Principles of Economics	4
ES 203	Electrical Systems	4
	Total	16

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
	Total	16
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*
EP 380	Nanotechnology, Entrepreneurship and Ethics	4

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

EP 410	Intro to MEMS	4
EP 415	Engineering Physics Project I	4
	Engineering Elective or	4
EP 408	Microsensors	
	Total	16

	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:

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
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

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 105	Engineering Chemistry I	4
CHEM 107	Engineering Chemistry II	4
Total		**47**

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	4
	Engineering Elective	8
CSSE 120/ME 123	Computer Programming	4
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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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.	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	
		or	4
CHEM	111	General Chemistry I	
RH	131	Rhetoric and Composition	
		or	4
HSS		Elective	
CLSK	100	College and Life Skills	1
CSSE	120	Introduction to Software Development	4
			18

Winter Term

			Credit
MA	112	Calculus II	5
PH	112	Physics II	
		or	4
PH	111	Physics I	
CHEM	111	General Chemistry I	
		or	
AB	101	Essential Biology (or higher level AB course)	4
HSS		Elective	
		or	4
RH	131	Rhetoric Composition	
			17

Spring Term

			Credit
MA	113	Calculus III	5
PH	113	Physics III	
		or	4
PH	112	Physics II	
MA	190	Contemporary Mathematics Problems	2
HSS		Elective	4
			15

Junior Year

Fall Term

			Credit
MA		Elective	4
		Technical Elective	4
		Technical Elective	4
HSS		Elective	
		or	4
RH	330	Technical and Professional Communication	

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)	
		or	4
PH	113	Physics III	
*CSSE	220	Object-Oriented Software Development	4
			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)	
MA	492	Senior Project I (2 hours)	
		or	4
MA	496	Senior Thesis I (4 hours)	
		Free Elective	4
		Free Elective	4

			16
Winter Term			*Credit*
MA	*366*	*Functions of a Real Variable*	*4*
MA		*Elective*	*4*
		Technical Elective	*4*
HSS		*Elective* or	*4*
RH	330	Technical and Professional Communication	
			16
Spring Term			*Credit*
MA		Elective	4
MA		Elective Technical Elective	4
HSS		Elective or	4
RH	330	Technical and Professional Communication	
			16
HSS		HSS	4
			16
Winter Term			*Credit*
MA	493	Senior Project II (2 hours) or	2
MA	497	Senior Thesis II (2 hours)	
MA		Elective	4
		Free Elective	4
		Free Elective	4
		Free Elective	4
			18
Spring Term			*Credit*
MA	494	Senior Project III (2 hours) or	2
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 Specroscopy
- 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

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.

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**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

Thernal 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		
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	4
HSS	Elective	
	Total	16
Winter Term		*Credit*
MA 112	Calculus II	5
PH 112	Physics II	4
ME 123	Computer Applications I	4
RH 131	Rhetoric and Composition split fall or winter with	4
HSS	Elective	
	Total	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
	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 and Mechanics of Materials I	4
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 split winter or spring with	4
ME 323	Computer Applications II	(2)

Senior Year		
Fall Term		*Credit*
ME 430	Mechatronic Systems split fall or winter with	4
ME 421	M.E. Lab and *Tech Elective	(2+4)
ME 406	Control Systems or	4
EM 406	Vibration Analysis	(4)
ME 480	Machine Component Design split Jr. spring or Sr. fall with	4
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

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

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. Atechnical 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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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

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
MA	212	Matrix Algebra and Systems of 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

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

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			*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	
			16

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

Winter Term			*Credit*
OE	485	Electro-Opt. & App.	4
HSS		Elective	4
		Engineering Elective	4
OE	417	Opt Eng Des III	4
			16

Spring Term			*Credit*
		Engineering Elective	4
HSS		Elective	4
HSS		Elective	4
		Free Elective	4
			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.

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

Rose-Hulman
Institute of Technology
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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, Magnetics, 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	4
HSS		Elective	
EM	104	Graphical Communications	2
			16

Winter Term

			Credit
PH	112	Physics II	4
MA	112	Calculus II	5
CHEM	111	General Chemistry I	4
		Computing Elective*	2-4

Sophomore Year

Fall Term

			Credit
		Free Elective†	4
PH	235	Many Particle Physics	4
MA	211	Differential Equations	4
PH	292	Physical Optics	4
			16

Winter Term

			Credit
PH	255	Fund. of Modern Physics	4
		Elective	4
HSS		Technical Elective	4
MA	212	Matrix Algebra and Systems of 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
Spring Term			*Credit*
PH	113	Physics III	4
MA	113	Calculus III	5
CHEM	113	General Chemistry II	4
HSS		Elective	
		or	4
RH	131	Rhetoric and Composition	
			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
			16
Winter Term			*Credit*
PH	317	Electromagnetism	4
PH	401	Intro Quantum Mechanics	4
HSS		Elective	4
		Physics Elective†	4
			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
			16

Senior Year

Fall Term			*Credit*
Math		Elective†	4
		Technical Elective†	4
HSS		Elective	4
		Free Elective	4
			16
Winter Term			*Credit*
PH	425	Advanced Physics Lab II	4
HSS		Elective	4
		Technical Elective†	4
		Free Elective†	4
			16
Spring Term			*Credit*
		Technical Elective†	4
OE	450	Laser Sys & App	
		or	4
		Physics Elective	
		Free Elective	4
		Physics Elective†	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
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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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	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

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	4
MA	275	Equations Discrete & Combinatorial Algebra I	4
			16

Winter Term

			Credit
CSSE	220	Object-Oriented Software Development	4
MA	112	Calculus II	5
PH	112	Physics II	4
HSS		Elective	4
			17

Spring Term

			Credit
CSSE	132	Introduction to Computer Systems Design	4
MA	113	Calculus III	5
HSS		Elective	4
Science		Elective	4
			17

Junior Year

Fall Term

			Credit
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
			16

Winter Term

			Credit
CSSE	332	Operating Systems	4
CSSE	374	Software Design	4
HSS		Elective	4
		Domain track course	4
			16

Spring Term

			Credit
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
			16

Winter Term

			Credit
CSSE	230	Data Structures and Algorithm Analysis	4
CSSE	333	Database Systems	4
MA	375	Discrete & Combinatorial Algebra II	4
		Domain track course	4
			16

Spring Term

			Credit
CSSE	304	Programming Lang. Con	4
CSSE	376	Software Quality Assurance	4
MA			
RH	330	Elective Technical and Professional Communication	4
			16

Senior Year

Fall Term

			Credit
CSSE	477	Software Architecture	4
CSSE	497	Senior Project I	4
HSS		Elective	4
		Domain track course or free elective	4
			16

Winter Term

			Credit
CSSE	498	Senior Project II	4
CSSE		Elective	4
HSS		Elective	4
Free		Elective	4
			16

Spring Term

			Credit
CSSE	499	Senior Project III	4
HSS		Elective	4
Free		Elective	4
			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 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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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 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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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

			Credit
MS	101	Leadership and Personal Development	1
MS	102	Introduction to Tactical Leadership Basic Tactical Leadership	1
MS	103		1

Sophomore Year

			Credit
MS	201	Innovative Team Leadership	2
MS	202	Foundations of Tactical Leadership Foundations of Tactical Leadership II	2
MS	203		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 Leadership in a Complex World II	4
MS	403		4

TOTAL CREDITS REQUIRED: 33

*All contracted cadets must attend Leadership Laboratories and Physical Training..

Rose-Hulman Institute of Technology
5500 Wabash Avenue
Terre Haute, IN 47803
812-877-1511

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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)
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Military
Pre-Professional Programs

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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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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-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 205 Cellular Physiology 4R-0L-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 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.

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 earths 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 progess 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 Systems4R-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 361Biomaterials3R-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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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, toperform 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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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 environmentalanalytical 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-IC 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 orCHEM 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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Civil Engineering

Professors Aidoo, Chapman, Hanson, Kershaw, Lovell, Mueller, Price, 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 databases, computational software, 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 tools 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 250 Sustainable Civil Engineering Design 2R-0L-2C S Pre:
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 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 110 or equivalent and 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 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 n 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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Graduate Studies

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College & Life Skills

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.

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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Computer Science & Software Engineering

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 handing. 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 anapplication no longer needs. In this course, students will explore the classical problems of garbagecollection such as detecting unused objects and reclaiming the space allocated to them. Students willsurvey the GC literature to become familiar with the current state of the art and future researchdirections. Students will explore techniques used to implement state-of-the-art garbage collectionalgorithms 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: 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 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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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, 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 algorithims 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 intrusctor
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 stragies 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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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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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 devises 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

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
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Military Science (Army ROTC)
Multi-Disciplinary Studies
Optical Engineering
Physics
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Humanities and Social Sciences

Areas of Study

Global Studies Ideas and Art Society and Values Modern Languages

Majors

- International Studies (second major only)
- Economics

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, Christ, Clark, Dyer, Garcia, Gardner, Hartner, Heeter, Hirotani, House, Kim, Kukral, Letsinger, Li, Livingston, Martland, Michel, Minster, Smit, Smith, C. 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

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

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 coverscontemporary 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 Psychology4R-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 Psychology4R-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-0L-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 oftexts 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-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
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
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:
    - 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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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 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 applications, famous problems, and outstanding problems of great significance.

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 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 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-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, 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 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.
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 algorithmand turbulence modeling. Survey of solution strategy includes both the finite volume and the finite difference methods. Issues on formal orderof 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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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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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
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Optical Engineering

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.

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
Light, optics, and optical instruments, 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.

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, and an introduction to optical instruments. Introduction to third order aberration and 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 212
Components of optical systems; stops, pupils, windows; introduction to lasers light and optical sources; radiometry and photometry; optical transfer function; optoelectronics; LEDs; detectors and detector arrays; noise in detectors.

OE 360 Optical Materials and Opto-Mechanics 4R-0L-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-0L-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

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
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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. Teamoriented 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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Physics

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, Lyupunov 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, Fraunhoffer 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 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 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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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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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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