Rose-Hulman / Foundation-Coalition
Sophomore Engineering Curricula

Detailed Information
What is the Rose-Hulman Sophomore Engineering Curriculum?

An eight-course sequence that integrates core material in engineering science and mathematics.

– Designed for all engineering majors.
– Developed by a multi-disciplinary faculty team.
– Required of all electrical, computer, and mechanical engineering students.
What’s in our Core?

<table>
<thead>
<tr>
<th>Diff. Equations I</th>
<th>Dynamics</th>
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<tbody>
<tr>
<td>Fluid Mechanics</td>
<td>Circuits</td>
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<tr>
<td>Thermodynamics</td>
<td>Diff. Equations II</td>
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<tr>
<td>Statistics</td>
<td>System Dynamics</td>
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<tr>
<td>Matrix Algebra</td>
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32 Qtr. Credit Hours
Sophomore Engineering Curriculum
Our New Approach

**Fall**
- Diff. Equations & Matrix Algebra I (4)
- Conservation & Accounting Principles (4)

**Winter**
- Diff. Equations & Matrix Algebra II (4)
- Fluid & Thermal Systems (3)
- Electrical Systems (3)
- Mechanical Systems (3)

**Spring**
- Statistics for Engineers (4)
- Analysis & Design of Engineering Systems (5)

30 Qtr. Credit Hours
Sophomore Engineering Curriculum

Advantages for Students

- Participate in a coordinated curriculum that consciously stresses the links between engineering science and mathematics.
- Provide a common foundation of engineering science and mathematics knowledge for future learning.
- Learn to apply a common framework for problem solving based upon an understanding of the conservation and accounting principles.
- Learn to handle open-ended problems.
- Work with multi-discipline problems.
- Learn cooperatively and work in teams.
- Use computer technology across the curriculum.
Sophomore Engineering Curriculum
A Brief History

Fall 1993
• Foundation Coalition funded by NSF.

1993-1994
• Institute considered various ideas for Sophomore Curriculum (Friday afternoon meetings)

Summer 1994
• Workshops on teaming, active learning, curriculum design. (Approximately 4 days total)
• Multidisciplinary faculty team developed overall framework for SEC. (12 faculty)
Sophomore Engineering Curriculum
A Brief History

1994-1995
• Met with departments and finalized proposal.
• Proposal for pilot approved by Institute.
• Required by electrical and computer engineering department.

Summer 1995
• Team of 12 faculty and 3 students developed detailed curriculum material for eight courses.
Sophomore Engineering Curriculum
A Brief History

1995-1996
• Offered RH/FC SEC for first time to 90 students
• Rose-Hulman required students to purchase a laptop computer.

1996-1997
• Adopted by mechanical engineering department for Fall 1998.

2000-2001
• Currently taken by 220-230 mechanical, electrical, and computer engineering students.
Sophomore Engineering Curriculum

Curriculum Structure

FALL Quarter ................................................. 8 Credit Hours
   MA 221 - Differential Equations & Matrix Algebra I (4)
   ES 201 - Conservation & Accounting Principles (4)
WINTER Quarter ............................................ 13 Credit Hours
   MA 222 - Differential Equations & Matrix Algebra II (4)
   ES 202 - Fluid & Thermal Systems (3)
   ES 203 - Electrical Systems (3)
   ES 204 - Mechanical Systems (3)
SPRING Quarter ............................................. 9 Credit Hours
   MA 223 - Engineering Statistics (4)
   ES 205 - Analysis & Design of Engineering Systems (5)
TOTAL CREDITS ............................................. 30 Credit Hours
ES 201
Conservation & Accounting Principles
Fall Quarter - 4 credits
Conservation & Accounting Principles

- Basic Systems, Accounting, and Modeling Concepts
- Laws
  - Conservation Laws: Mass, Charge, Energy, Linear & Angular Momentum
  - Accounting Principle: Entropy
- Simple open and closed systems
ES 202
Fluid & Thermal Systems

Winter Quarter - 3 credits
Shared 3-hr Laboratory
Fluid & Thermal Systems

• Thermodynamic Properties
  – Pure simple compressible substances
  – Gases: ideal gas & Z-Chart
  – Solids/Liquids: incompressible substance
• Applications to Open and Closed Systems
• Simple Cycles
Fluid & Thermal Systems

- Dimensional Analysis
- Mechanical Energy Equation
  - Bernoulli Equation
  - Pipe Flow of Incompressible Fluids
  - Pump/Turbine Efficiencies
- Lift and Drag
- Hydrostatics
Fluid & Thermal Systems

Laboratory Experiences
Lab 1 - Dimensional Analysis
Lab 2 - Torricelli’s Principle, Friction Factors, Water-Wall Exhibit
Lab 3 - Back-pressure steam turbine
ES 203
Electrical Systems
Winter Quarter - 3 credits
Shared 3-hr Laboratory
Electrical Systems

- Circuit Elements
- Kirchhoff’s Laws
- Equivalent circuits and Voltage and current dividers
- Operational amplifiers
- First, second, and higher order circuits
- Transient and steady-state behavior
- AC circuits and power
ES 204
Mechanical Systems

Winter Quarter - 3 credits
Shared 3-hr Laboratory
ES204 - Mechanical Systems

- More Kinematics
  - Normal-Tangential coordinates
  - Radial - Transverse coordinates
  - Dependent motion
  - Relative motion
  - Rigid bodies

- Impacts (coefficient of restitution)
Mechanical Systems (cont.)

- Use Working Model, Maple, Concept maps
- Three labs
- Immediate application to kinetics problems
- Combination problems
Assessment - Is it worse?

• Year 2 - Gave 17 identical multiple choice and 1 identical workout problem to ES204 and to dynamics students
  – 4 ES204 sections/3 professors
  – 5 Dynamics sections/3 professors
• Year 3 - Gave identical finals to ES204 and to dynamics students (20 multiple choice, 3 workout)
  – 4 ES204 sections/2 professors
  – 5 Dynamics/3 professors
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Workout problems*

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* Essentially an “A” solution
ES 205
Analysis & Design
of Engineering Systems

Spring Quarter - 5 credits
3-hr Laboratory
ES205 - Analysis & Design of Engineering Systems

- Pre-vibrations/controls
- Mechanical, Electrical, Electro-mechanical, Hydraulic, Fluid, Thermal systems
- Governing differential equations
- System Response
- System identification
Systems Concepts in ES205

- Modeling of system elements
- Equations of motion
  - Natural frequency, Damping ratio, Static gain
  - 2nd order matrix form, state space form
- Transfer functions
- Free response
  - log decrement
Systems Concepts in ES205 (cont.)

- Forced Response
  - Step input
    - performance specifications
  - Harmonic input
    - Frequency response plots
  - General periodic forcing
    - Fourier Series
- Simulink, Matlab and Maple
Analysis & Design of Engineering Systems

Laboratory

• Introduction to the design process.
• Teams of students study and develop design specifications** for products.
• Includes written and oral presentations.

Mathematics Sequence

- Differential Equations & Matrix Algebra I
- Differential Equations & Matrix Algebra II
- Statistics for Engineers
Sophomore Engineering Curriculum

Mathematics

• Stresses Linear Structures
  – systems of algebraic equations (Ax=b)
  – 1st & 2nd order differential equations
  – systems of differential equations
  – Laplace transforms
  – Fourier series
  – linearization

• Applications of Statistics

• Students have laptops with access to MAPLE, MATLAB, and MINITAB.
Differential Equations & Matrix Algebra I

• Basic Matrix Algebra
  – systems of linear equations (algebraic and geometrical viewpoints)
  – least squares
  – eigenvalues and eigenvectors

• Differential Equations
  – Review of first-order de’s
  – Second-order linear de’s with constant coefficients (homogeneous and non-homogeneous cases)

• Introduction to Complex Arithmetic
Differential Equations & Matrix Algebra II

- Laplace Transforms
- Systems of First-Order Linear DE’s
  - solution using Laplace transforms
  - investigation of solution structure determined by eigensystems.
- Phase Portrait Analysis and Stability of Critical Points for Systems of Equations
- Approximation of Functions
  - Taylor and Fourier series
Statistics for Engineers

• Introductory course in statistical data analysis emphasizing
  – hypothesis testing
  – analysis of variance
  – quality control charts
  – simple and multiple regression
  – simple experimental designs

• Computer Tools: MINITAB and Excel
Experience with SEC at RH

- Reduced engineering credit hours from 20 to 18 without sacrificing material.
- Faculty like
  - common problem solving approach that does not reinforce “plug and chug.”
  - emphasis on modeling assumptions and mathematics that apply across disciplines.
  - ability to restructure material and “spiral” back, e.g. dynamics in two courses.
Experience with SEC at RH

• Students comment favorably on “integration” and “big picture” view of curriculum.

• Quantitative comparisons
  – SEC students did better than traditional students on final exam “workout” problems in dynamics, e.g. 20-40% more SEC students got problems right.
Student Comments after Completing the SEC

Student A

“ES201 was an excellent foundation to start on. A solid handle on this class is a must for success in the following classes. All classes were connected to this class.”
Student Comments

Student B

“The sophomore curriculum has won me over. At first, I thought it was a complete waste of time. Then during winter quarter I saw the importance of it. Now, I am glad to have gone through it. The book didn’t help much, it was vague and made the class more difficult.”
Student Comments

Student C

“I was very pessimistic about the course (ES205) at the beginning of the quarter. This course defeated every pessimistic premise I had before it was completed. This course brought all the engineering disciplines together and, at the very least, made this skeptical EE a believer in the SEC. Not only was the course an eye-opener, but it also enhanced my ability to solve general complex-system problems regardless of what discipline they came from?”
Student Comments

Student D

“Perhaps one of my other gripes with the class is that it is so different from freshman physics. I actually prefer this method of teaching when it comes to frictions, tensions, angular momentum, etc. These are all topics with which I felt uncomfortable during freshman physics although I understand them better now. In the future, I would appreciate seeing the ConApps and Physics curriculums more closely integrated so that students only have to learn concepts once."
For additional information about the RH Sophomore Engineering Curricula or the Systems, Accounting, and Modeling Approach contact ---

Don Richards
Rose-Hulman Institute of Technology
5500 Wabash Ave. - CM 160, Terre Haute, IN 47803

Email: donald.e.richards@rose-hulman.edu
URL: http://www.rose-hulman.edu/~richards
Phone: 812-877-8477

Or check the Foundation Coalition Web Site at http://www.foundationcoalition.org