Biology
Biochemistry
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Computer Science
Economics
Electrical Engineering
Engineering Physics
International Computer

Army ROTC (Military)

Pre-Professional Programs

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TECHNICAL MINORS

Biology
Astronomy
Biochemical Engineering
Biochemistry and Molecular Biology
Biomathematics
Biomedical Engineering
Chemical Engineering
Chemistry
Computational Science
Computer Engineering
Computer Science
Electrical Engineering
Entrepreneurship Minor
Environmental Chemistry
Environmental Engineering
Mathematics
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
Geographvironmental Engineering

- Philosophy and Religion
- Political Science
- Psychology
- Spanish
- Theatre and Drama

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

Three of ten elective courses are required.

ECE551: Digital VLSI
ECE552: Analog Integrated Circuit Design
ECE553: RF Integrated Circuit Design
ECE343: High-Speed Digital Design (required for CPE program)
ECE416: Intro to MEMS
ECE419: Advanced MEMS
ECE454: System Level Analog Electronics
ECE557: Analog Test and Product Engineering (if not used for required testing course)

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

Imaging Project

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

Imaging Systems Program Director

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

Imaging Systems Faculty

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

CERTIFICATE IN SEMICONDUCTOR MATERIALS AND DEVICES

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

Required Courses

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

Electives

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

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

Overall aim of the Certificate

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

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

THE MANAGEMENT STUDIES PROGRAM

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

Statement of Objectives

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

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

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

Requirements:

1. All of the following core Courses:
   SV151 Principles of Economics

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

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in advance from the head of the department concerned.

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ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Biology

The twenty-first century will see unparalleled advances in the biological sciences. Disciplines such as 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 biology. Biologists will be at the forefront of these advances and will drive the medical, agricultural, environmental and industrial applications of biological sciences.

The 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.

BIOLOGY PLAN OF STUDY

Freshman Year

Fall Term		Credit
BIO 110	Cell Structure and Function	4
CHEM 111	General Chemistry	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
	Total	14

Winter Term		Credit
BIO 120	Comparative Anatomy & Physiology	4
CHEM 113	General Chemistry II	4
MA 112	Calculus II	5
RH 131	Rhetoric & Compostition	4
	Total	17

Spring Term		Credit
BIO 130	Evolution and Diversity	4
CHEM 115	General Chemistry III	4
MA 113	Calculus III	5
BE 100	Problem Solving in the Biological Sciences and Engineering	4
	Total	17

Sophomore Year

Fall Term		Credit
BIO 210	Mendelian & Molecular Genetics	4
CHEM 251	Organic Chemistry I	3
CHEM 251L	Organic Chemistry I Laboratory	1
PH 111	Physics I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
	Total	16

Winter Term		Credit
BIO 220	Prokaryotic Cell & Molecular Biology	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
PH 112	Physics II	4
RH 330	Technical and Professional Communication	4
	Total	16

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Computer Engineering
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Engineering Physics
International Computer Science
Mathematics
Mechanical Engineering
Optical Engineering
Physics
Software Engineering

Additional Programs of Study

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

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		

BE310	Analysis of Physiological Systems I

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

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Biochemistry

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

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

BIOCHEMISTRY PLAN OF STUDY

Freshman Year

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

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

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

Sophomore Year

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

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

Spring Term		Credit
CHEM 253	Organic Chemistry III	3

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Physics
Software Engineering

Additional Programs of Study

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

MISSION STATEMENT

Much of biology incorporates the mathematical and computational sciences. The biomathematics degree blends mathematics, biology, and computer science in preparation for careers in the quantitative life sciences and for continued graduate studies. The degree's mission is to provide a world class undergraduate education in applied mathematics in support of the life sciences.

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

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

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

PROGRAM GOALS AND OBJECTIVES

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

PROGRAM OUTCOMES

Graduates will be prepared for graduate study in any of the sister fields as well as for careers in the quantitative life sciences. Each graduate will complete a capstone research experience s stuce s stuce s prnd02inl and is u7d02inttencan educatioternnd02inl and 156blical s snbiologO

Freshman Year

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

Winter Term		Credit
PH 111	Physics I	4
CHEM 113	General Chemistry II	4
MA 112	Calculus II	5
HSS		4
	Total	17

Sophomore Year

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

Winter Term		Credit
BIO 220	Microbiology	4
MA 212	Matrix Algebra & Systems of D.E.	4
MA 381	Intro. to Probability	4

CHEM 330 Biochemistry I 4R-0L-4C W Prereq. CHEM 252

Biomedical engineering is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Biomedical engineering is attractive to some students because they want to help others. Some are drawn to it for the excitement of working with living systems and applying technical solutions to the complex problems. The biomedical engineer is a health care professional, a group which includes physicians, nurses, and technicians. Biomedical engineers may be called upon to design medical devices like pacemakers, coronary stents, or prosthetics hips & knees. The biomedical engineer may also bring together knowledge from many sources to develop new manufacturing or medical procedures. Some biomedical engineers will carry out research to acquire new knowledge. According to the Whitaker Foundation website, (www.whitaker.org), and based on a forecast by the US Bureau of Labor Statistics (http://www.bls.gov), biomedical engineering jobs will climb almost twice as fast as the overall average for a 26.1 percent gain by 2012. Overall job growth is projected to be 14.8 percent. This is an exciting time for biomedical engineering at Rose-Hulman. The biomedical engineering program will produce engineers with the medical and biological knowledge needed to solve many of the health care problems that face our society. The program will prepare graduates for careers in the biotechnology and health-related industries, as well as in government and industrial research laboratories. Those wishing to continue their studies in graduate school or health professions programs will be exceptionally well qualified to do so.

Biomedical Engineering Program Educational Objectives

Objectives are defined as "expected accomplishments of graduates during the first several years following graduation from the program."

- Graduates will apply the theories and concepts of biology, mathematics, physical science and engineering science essential to being a successful biomedical engineer.
- Graduates will apply practical and technical skills required for biomedical engineering practice.
- Graduates will work and communicate effectively with all of the people around them.
- Graduates will exercise their professional responsibilities towards society.
- Graduates will apply design principles to open-ended problems subject to technical, practical and societal constraints.

Biomedical Engineering Student Outcomes

By the time students graduate with a Biomedical Engineering Degree from Rose-Hulman, they will:

- have a strong background in and be able to apply knowledge of biology, mathematics, and the physical and engineering sciences.
- be able to describe challenges associated with the interactions of living tissues with engineered systems and propose safe and effective strategies for meeting these challenges.
- have an advanced and current body of knowledge within biomaterials, biomechanics, or biomedical instrumentation.
- be able to work safely, independently, and confidently in a laboratory environment.

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

Additional Programs of Study

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

HSS or RH330	or HSS Elective	
EM 204	Statics and Mechanics of Materials II	4
	Total	16

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

Spring Term		Credit
SV 304	Bioethics	4
BE 320	Physiological Systems II	4
BE 390	Principles of Biomedical Engineering Design	2
BE	Area	4
	Total	14

	Free Elective	4
BE	Area Elective	4
	Total	16

Winter Term		Credit
BE 420	Biomedical Engineering Design II	4
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
	Total	16

Spring Term		Credit
BE 430	Biomedical Engineering Design III	2
HSS	Elective	4
	Free Elective	4
BE	Area Elective	4
	Total	14
	Total credits required:	192

Biomedical Engineering Areas of Concentration

To receive the B.S. Degree Program in Biomedical Engineering, each student must satisfy the requirements of one of three Biomedical Engineering Areas of Concentration: Biomaterials, Biomechanics or Biomedical Instrumentation. The course options for each of these Areas are given below. A total of 16 credits (including required courses) from one of the lists must be taken.

It is not permissible to "mix and match" courses from different area lists without written permission from the BBE department head.

Biomedical courses that are offered as special topics courses (e.g. BE491 or BE597) may only be used with the written permission of the department head. Students should work out their schedule in advance to ensure that all graduation requirements are met.

BIOMATERIALS CONCENTRATION

Course	Title
BE 417	Advanced Materials
BE 516	Introduction to MEMS
BE 539	Multiscale Biomechanics
BE 560	Tissue-Biomaterial Interactions
BE 570	Introduction to Tissue Engineering
CHE 315*	Materials Science and Engineering
CHE 441	Polymer Engineering
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
ME 328*	Materials Engineering

*CHE 315 OR ME 328 may be used, but not both
**ME 317(3 cr) to be taken concurrently with BE317(1 cr)

BIOMEDICAL INSTRUMENTATION CONCENTRATION

Course	Title
BE 340	Biomedical Instrumentation and Signal Processing
BE 350	Biocontrols

BE 516	Introduction to MEMS
BE 435/535	Biomedical Optics
BE 555	Electrophysiology
ECE 230	Microcontrollers and Computer Architecture
ECE 480	Introduction to Image Processing
ME 430	Mechatronic Systems
BE 541	Medical Imaging
BE 543	Neuroprosthetics

BIOMECHANICS CONCENTRATION

Course	Title
ME 317**	Design for Manufacturing
and	
BE 317**	Design for Biomedical Manufacturing
BE 525	Biomedical Fluid Mechanics
BE 531	Biomechanics II
BE 534	Soft Tissue Mechanics
BE 539	Multiscale Biomechanics
BE 545	Orthopaedic Biomechanics
BE 550	Research Methods in Biomechanics
EM 403	Advanced Mechanics of Materials
ME 422	Finite Elements for Engineering Applications
ME 520	Computer-Aided Design and Manufacturing
ME 522	Advanced Finite Element Analysis

Biomedical Engineering Thesis Option:

The biomedical engineering thesis option is intended for students who complete a substantive research project in this field. In order to complete this thesis option a student must:

1. Pass a minimum of 8 credit hours of BE 492.
2. Perform research in BE492 that involves the same research project and is completed under the direction of a departmental faculty mentor. None of these credits may be used to fulfill the biomedical engineering area elective requirement.

BE350 **	Biocontrol Systems **
BE361 and BE353	Biomaterials and Biomaterials Lab
BE435/535	Biomedical Optics
BE/MA482	Bioengineering Statistics
BE520	Introduction to Brain Machine Interfaces
BE525	Biomedical Fluid Mechanics
BE531	Biomechanics II
BE534	Soft Tissue Mechanics
BE539	Multiscale Biomechanics
BE543	Neuroprosthetics
BE545	Orthopaedic Biomechanics
BE560	Tissue-Biomaterial Interactions
BE570	Introduction to Tissue Engineering

* BE340 cannot be used for a BE minor by students majoring in electrical or computer engineering.
** BE350 cannot be used for a BE minor by students who have taken ECE320 or ME406.

In addition to courses in the above area concentration, students are required to have completed at least 12 credits of basic engineering courses. These courses may be chosen from the list below:

BE201	Biomedical Instrumentation and Measurements
EM121	Statics & Mechanics of Materials I
EM204	Statics & Mechanics of Materials II
EM301	Fluid Mechanics
ECE180	Introduction to Signal Processing
ECE203 *	DC Circuits
ECE204	AC Circuits
ES201	Conservation & Accounting Principles
ES202	Fluid Systems
ES203 *	Electrical Systems
ES204	Mechanical Systems
CHE201	Conservation Principles and Balances

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

	Total	16

Winter Term		Credit
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
	Total	16

Spring Term		Credit
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
HSS	Elective	4
	Total	16

	Total	16

Winter Term		Credit
CHE 202	Basic Chemical Process Calculations	4
CHEM 252	Organic Chemistry II	3
CHEM 252L	Organic Chemistry II Lab	1
MA 212	Matrix Algebra and Systems of Differential Equations	4
HSS	Elective	4
	Total	16

Spring Term		Credit
MA 223	Engineering Statistics I	4
CHEM 225	Analytical Chemistry I	4
HSS	Elective	4
CHE 315	Materials Science	4
	Total	16

Junior Year (A1 Schedule)

Fall Term		Credit
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
CHE 315	Materials Science	4
CHEM 225	Analytical Chemistry I	4
	Total	16

Winter Term		Credit
CHE 321	Applications of Heat and Mass Transfer	4
CHEM 360	Intro Physical Chemistry	4
MA 223	Engineering Statistics I	4
RH 330	Technical and Professional Communication	4
	Total	16

Spring Term		Credit
CHE 404	Kinetics & Reactor Design	4
CHE 411	Chemical Engineering Lab I	3
ECE 206	Elements of Electrical Engineering	4
	Elective (Free)	4
	Total	15

Junior Year (A2 Schedule)

Fall Term		Credit
CHE 301	Fluid Mechanics	4
CHE 303	Chemical Engineering Thermodynamics	4
	Elective (Approved)	4
RH 330	Technical and Professional Communication	4
	Total	16

Winter Term		Credit
CHE 304	Multi-Component Thermodynamics	4
CHE 320	Fundamentals of Heat and Mass Transfer	4
ECE 206	Elements of Electrical Engineering	4
HSS	Elective	4
	Total	16

Spring Term		Credit
CHE 321	Applications of Heat and Mass Transfer	4
CHE 411	Chemical Engineering Lab I	3

	Free Elective(Free)	4
	Free Elective(CHE)	4
	Total	17

CHE 416	Design I	4
	Free Elective(Free)	4
	Total	17

Winter Term		Credit
CHE 413	Chemical Eng. Lab III	4
CHE 417	Design II	4
CHE 440	Process Control	4
HSS	Elective	4
	Total	16

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
HSS	Elective	4
	Elective(Approved)	4
	Elective(CHE)	4
	Total	18
	Total credits required:	194

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

Students need to take CHE 502 (Transport Phenomena) and 3 additional courses from the list below. Other courses may be substituted only with prior approval by the Department Head.

- CHE 310 Numerical Methods
- CHE 499 Directed Research (4 credit hours)
- CHE 504 Advanced Reactor Design
- CHE 513 Advanced Thermodynamics
- MA 336 Boundary Value Problems

Energy Production and Utilization

Students need to take 4 courses from the list below. Other courses may be substituted only with approval of the Department Head.

- CHE 465 Energy and the Environment
- CHE 512 Petrochemical Processes
- ME 407 Power Plants
- ME 408 Renewable Energy
- ME 450 Combustion

Industrial and Process Engineering

Students need to take CHE 470 (Safety, Health, and Loss Prevention), CHE 540 (Advanced Process Control), 2 courses from the Math List below, and 1 course from the Engineering Management List below. Other courses may be substituted only with approval of the Department Head.

Math List

MA 385 Quality Methods
MA 487 Design of Experiments
MA 387 Statistical Methods in Six Sigma
MA 444 Deterministic Models in Operations Research

Engineering Management List

EMGT524 Production/Operations Management
EMGT527 Project Management
EMGT562 Risk Analysis and Management
EMGT581 Multi-objective Optimization
EMGT586 Supply Chain Management
EMGT587 Systems Engineering
EMGT588 Quality Management I
EMGT589 Manufacturing Systems

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Course	Numbers	Credits
General Chemistry	111, 113, 115	12
Organic Chemistry	251, 252, 253	12
Analytical Chemistry	225, 326, 327	12
Physical Chemistry	361, 362, 363	12
Inorganic Chemistry	441, 442	4
Biochemistry	330	4
Organic Structure		

	Chemistry Electives	
Total		24

*Approved list of chemistry electives include CHEM 253, CHEM 290 (up to two credit hours), CHEM 291, or any 300 or 400 level chemistry courses.

Minor in Chemistry for Chemical Engineering and Biology Majors

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
	Chemistry Electives*	12
Total		20

*The electives cannot count toward the student's major. Students who have taken CHE 303, 304 and CHEM 360 cannot count CHEM 361 or CHEM 362 toward the minor. No more than 2 credits of CHEM 290 can count toward the minor.

Environmental Chemistry Minor for Most Students

Course Number	Course Title	Credits
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
CHEM 115	General Chemistry III	4
CHEM 225	Analytical Chemistry	4
CHEM 251	Organic Chemistry I	4
CHEM 264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHEM 465	Energy and the Environment	4
Total		32

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

Course Number	Course Title	Credits
CHEM 225	Analytical Chemistry	4
CHEM 253	Organic Chemistry III	4
or CHEM 330	Biochemistry	4
CHEM 361	Physical Chemistry I	4
or CHE 303	Chemical Engineering Thermodynamics	4
CHEM 264	Introduction to Environmental Science	4
CHEM 371	Environmental Analytical Chemistry	4
CHE 465	Energy and the Environment	4
Total		24

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.

man

Fall		
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition or Elective(HSS)	4
CLSK 100	College & Life Skills	1
CE 101	Engineering Surveying	2
	Total	16

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
RH 131	Rhetoric and Composition or Elective(HSS)	4
CE 111	Geographic Info Systems	2
EM 102	Graphical Communications for CE	2
	Total	17

Spring Term		Credit
MA 113	Calculus III	5
EM 103	Introduction to Design	2
EM 120	Engineering Statics	4
	Elective (HSS)	4
	Total	15

		Credit	MA 211	Differential Equations	2
MA 211	Differential Equations	4	CHEM 1A 2105 25.445 45 285.1804 372.7057 2(17)Tj Vat83 Algebra Engineer		0.592F
CHEM 1A 2105 25.445 45 285.1804 372.7057 Tm (			)TTl632 25.445 -11.835 re 8Tj uquations		4

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

Computer Engineers (CPE) are electrical engineers that have additional training in the areas of software design and hardware-software integration. Common CPE tasks include writing embedded software for real-time microcontrollers, designing VLSI chips, working with analog sensors, designing mixed signal circuit boards, and designing operating systems. Computer engineers are also well-suited for research in the field of robotics, which relies on using computers together with other electrical systems. Below is a recommended plan of study for CPE.

CPE program educational objectives

Computer Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;
2. Function independently and in leadership positions within multidisciplinary teams;
3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;
4. Adapt and independently extend their learning to excel in fields about which they are passionate;
5. Strengthen teams and communities through collaboration, effective communication, public service, and leadership.Cof send abve tivesFaat hadeComs suiall:

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Freshman Year	
Fall Term	Credit

Sophomore Year	
Fall Term	Credit

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE180	Introduction to Signal Processing	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE300	Continuous-Time Signals Systems	4
ECE380 or ECE310	Discrete-Time Signals and Systems or Communication Systems	4

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE204	AC Circuits	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE351	Analog Electronics	4

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE204	AC Circuits	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE180	Introduction to Signal Processing	4
ECE230	Introduction to Embedded Systems	4
ECE233	Introduction to Digital Systems	4
ECE205	Circuits and Systems	4
ECE332	Computer Architecture II	4

Course	Course Title	Credits

Course	Course Title	Credits

Number				
ECE203 or ES203	DC Circuits or Electrical Systems	4		
ECE204	AC Circuits	4		
ECE370	Power and Energy Systems	4		
ECE371	Sustainable Energy Systems	4		
ECE470	Power Systems I	4		
ECE471	Industrial Power Systems	4		

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.

Computer Science Program Educational Objectives

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

Additional Programs of Study

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

MA473 and CSSE474 or MA474, and either CSSE487-9 or CSSE494-6 or CSSE497-9; MA111, MA112, MA113, MA212, MA275, MA375, MA381; ECE332; PH111, PH112; CHEM111; RH131, RH330; CLSK100.

2. Sixteen credits of additional computer science courses numbered between 200 and 492. No more than four credits may be at the 200 level, and none of the credits may be from CSSE372, 373, 375, 376, and 477. The student's academic advisor must approve the courses to satisfy this requirement. (Use of computer science courses numbered 490 through 492 to fulfill this requirement must be approved by the department head).
3. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the computer science major.
4. Eight additional credits of technical electives, consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
5. Twenty-eight credits of additional courses offered by the Department of Humanities and Social Sciences. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences.
6. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
7. A total of 192 credits.

Area Minor in Computer Science

Advisor: J.P. Mellor

Students majoring in Software Engineering may not receive a Computer Science minor.

Required courses

CSSE120 Introduction to Software Development
CSSE220 Object-Oriented Software Development
CSSE230 Data Structures and Algorithm Analysis
16 additional credits of computer science courses numbered above 200.
None of these may be CSSE 371-376, CSSE 477 or CSSE 493. Use of CSSE 490, CSSE 491 or CSSE 492 toward these 16 credits requires department head approval.

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Programs of Study

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 or HSS	Rhetoric and Composition or Elective	4
SV 150 or SV 152	Intro to Microeconomics or Intro to Macroeconomics	4
	Physical or Life Science	4
	Total	18
Winter Term		Credit
MA 112	Calculus II	5
CSSE 120	Intro to Software Development	4
RH 131 or SV 150 or	Rhetoric and Composition or Intro to Microeconomics or	4

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 or MA223	Introd to Probability with Applications to Statistics or	4

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

Additional Programs of Study

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

SV 152	Intro to Macroeconomics	
	Physical or Life Science	4
	Total	17
Spring Term		Credit
MA 113	Calculus III	5
RH 131 or SV 150 or SV 152	Rhetoric and Composition or Intro to Microeconomics or Intro to Macroeconomics	4
	Physical or Life Science	4
	*HSS Elective	4
	Total	17

Engineering Statistics	
Economics Elective	4
*HSS Elective	4
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. 24 credits of required Economics courses:
   SV150 Introduction to Microeconomics
   SV152 Introduction to Macroeconomics
   IA350 Intermediate Microeconomics
   IA351 Intermediate Macroeconomics
   SV450 Introduction to Econometrics
   XX456 Seminar for HSS Senior Projects
   XX457 Directed Study for HSS Senior Project
2. 20 additional credits in Economics electives.
3. 27 credits in required Mathematics courses:
   MA111, 112, 113 Calculus I, II, III
   MA211, 212 Differential Equations, and Matrix Algebra and Systems of Differential Equations
   MA223 Engineering Statistics I or
   MA381 Introduction to Probability
4. 12 additional credits in Mathematics other than MA351-356.
5. 36 credits in Humanities and Social Sciences. Each student must fulfill the HSS graduation requirements.
6. 24 credits in Physical or Life Sciences (Biology, Chemistry, Geology and Physics), with at least four credits each in Biology, Chemistry and Physics.
7. 4 credits in Engineering Management
8. 4 credits in Computer Science: CSSE 120
9. CLSK 100 (1 credit)

SUMMARY	Credits
Economics	44
Mathematics	39
Humanities and Social Sciences	36
Physical or Life Science	24
Engineering Management	4
Computer Science	4
Free Electives	40
Other:	
CLSK 100	1
TOTAL	192

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Electrical Engineering (EE) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. Common EE tasks include designing communication systems, energy conversion and power delivery, control systems applications, design of analog and digital systems, and others. Below is a recommended plan of study for EE

EE Program Educational Objectives

Electrical Engineering graduates shall:

1. Practice excellence in their profession using a systems approach encompassing technological, economic, ethical, environmental, social, and human issues within a changing global environment;
2. Function independently and in leadership positions within multidisciplinary teams;
3. Continue life-long learning by acquiring new knowledge, mastering emerging technologies, and using appropriate tools and methods;
4. Adapt and independently extend their learning to excel in fields about which they are passionate;

Freshman Year

Fall Term		Credit
PH 111	Physics I	4

Sophomore Year

Fall Term		Credit
MA 211	Differential Equations	4

MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
ECE 160	Engineering Practice	2
	Total	16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CSSE 120	Introduction to Software Development	4
RH 131	Rhetoric and Composition	4
	or	
HSS	Elective	
	Total	17

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ECE 203	DC Circuits	4
ECE 180	Introduction to Signal Processing	4
	Total	17

CHEM 111	General Chemistry	4
ECE 204	AC Circuits	4
ECE 233	Introduction to Digital Systems	4
	Total	16

Winter Term		Credit
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 230	Introduction to Embedded Systems	4
ECE 205	Circuits and Systems	4
HSS	Elective	4
	Total	16

Spring Term		Credit
MA 381	Introduction to Probability with Applications to Statistics	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 370	Power & Energy Systems	4
	or	
ECE 371	Sustainable Energy Systems	
ECE 250	Electronice Device Modeling	4
	Total	16

Junior Year

Fall Term		Credit
ECE 380	Discrete-Time Signals and Systems	4
ECE 351	Analog Electronics	4
ECE 340	Electromagnetic Fields	4
RH 330	Technical and Professional Communication	4
	Total	16

Winter Term		Credit
ECE 320	Linear Control Systems	4
HSS	Elective	4
ECE 341	Electromagnetic Waves	4
	Math/Science Elective	4
	Total	16

Spring Term		Credit
ECE 310	Communications Systems	4
	Area Elective	4
HSS	Elective	4
ECE 362	Principles of Design	3
	Total	15

Senior Year

Fall Term		Credit
ECE 460	Engineering Design I	3
	Math Elective	4
	Area Elective	4
HSS	Elective	4
	Total	15

Winter Term		Credit
ECE 461	Engineering Design II	4
	Tech Elective	4
	Area Elective	4
HSS	Elective	4
	Total	16

Spring Term		Credit
ECE 462	Engineering Design III	2
	Tech Elective	4
HSS	Elective	4
	Free Elective	4
	Free Elective	4
	Total	18

ECE371	Sustainable Energy Systems	
ECE380	Discrete-Time Signals and Systems	4
MA381	Introduction to Probability with Applications to Statistics	4
Total		64

AREA MINOR IN ELECTRICAL AND COMPUTER ENGINEERING (ECE)

The Area Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree.

Advisor Dr. Bob Throne

Requirements for Area Minor in ECE

- ECE203 or ES203 (not both)
- Plus five additional ECE courses, except ECE160, ECE362, ECE460, ECE461, ECE462, ECE466, and ECE206

Example Area Minor for Engineering Physics and Optical Engineering

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE180	Intro to Signal Processing	4
ECE204	AC Circuits	4
ECE205	Circuits and Systems	4
ECE300	Continuous Time Signals and Systems	4
ECE380 or ECE310	Discrete-Time Signals and Systems or Communication Systems	4

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE204	AC Circuits	4
ECE230	Intro to Embedded Systems	4
ECE233	Intro to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE351	Analog Electronics	4

Examples Area Minor for Computer Science and Software Engineering

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE204	AC Circuits	4
ECE230	Intro to Embedded Systems	4
ECE233	Intro to Digital Systems	4
ECE250	Electronic Device Modeling	4
ECE332	Computer Architecture II	4

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE180	Intro to Signal Processing	4
ECE205	Circuits and Systems	4
ECE230	Intro to Embedded Systems	4
ECE233	Intro to Digital Systems	4
ECE332	Computer Architecture II	4

Examples Area Minor for Mechanical Engineering

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE204 Required	AC Circuits	4
ECE370	Power & Energy Systems	4
ECE371	Sustainable Energy	4

Course Number	Course Title	Credits
ECE203 or ES203	DC Circuits or Electrical Systems	4
ECE180	Intro to Signal Processing	4
ECE204	AC Circuits	4
ECE233	Intro to Digital Systems	4
ECE250	Electronic Device Modeling	4

	Systems	
ECE470	Power Systems I	4
ECE471	Industrial Power Systems	4

ECE351	Analog Electronics	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

ENHANCED STUDY IN POWER SYSTEMS

Power Certificate

Take all of the following courses:

- ECE 473 Control of Power Systems, Pre: ECE 470
- ECE 472 Power Systems II, Pre: ECE 470
-

ECE 380 Discrete-Time Signals and Systems
ECE 312 Communication Networks
ECE 414 Wireless Systems
OE 360 Optical Materials and Opto-mechanics
OE 435 Biomedical Optics
OE 450 Laser Systems and Applications
OE 485 Electro-Optics and Applications

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Connect with Us

The Department of Physics and Optical Engineering has provided both science and engineering foundation at Rose-Hulman Institute of Technology through its physics and optics engineering programs. Physics is the foundation subject to all engineering and through the study in engineering physics we aim at blending a strong physics component with relevant engineering backgrounds that are usually necessary to work in areas such as semiconductor, optical technologies, biomedical applications, mechanical, electrical, and civil engineering, and polymer and biochemistry. The students will get their traditional undergraduate engineering education that has a broad foundation in mathematics, engineering sciences and technology. This program emphasizes problem solving skills and an understanding of engineering design to address the needs and challenges of the technology age and allow students to take a broad range of engineering careers.

Engineering Physics at Rose-Hulman will provide students with a unique opportunity to learn the foundation concepts of physics and make a concentrated study in micro and nano technology. Engineering physicist will be able to apply both scientific and engineering approaches to a wide variety of problems which otherwise is not possible with any traditional engineering or science degree. Rose-Hulman's engineering physics graduates will be trained to take up challenging jobs in engineering and development of new technologies or to pursue further studies in engineering or physics.

Mission: To provide a coherent foundation of physics for all majors and a strong foundation of physics, engineering physics and optical engineering for our majors so that all students can acquire education appropriate to their majors. The engineering disciplines of optical engineering and engineering physics enable students to practice in their dynamic and progressive engineering professional careers with responsibility to society.

Vision: To cultivate in the students responsibility, independence, and knowledge that allows them to be fully engaged in all disciplines, to continuously improve the curriculum, and to be engaged in professional development.

EP Program Educational Objectives

- Our graduates will set their career path and advance beyond their entry-level position or progress toward the completion of an advanced degree.
- Our graduates will contribute to society locally, nationally or globally
- Our graduates will collaborate within their organization; and be active in research and development in a relevant area of science and technology.
- Our graduates will continue to develop professionally.

EP Student Learning Outcomes

Outcome A:	Knowledge of the Fundamentals: An understanding of the fundamentals of science and engineering.
Outcome B1:	Interpreting Data: Ability to interpret graphical, numerical, and textual data.
Outcome B2:	System Level Modeling: Ability to model components and system level engineering problems.
Outcome B3:	Experimentation: Ability to design and conduct experiments to understand the relationships between variables in a problem which may or may not have been mathematically modeled before.

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

Additional Programs of comeccomeccomeccomeccome

Outcome C:	Design: Ability to design a product or process to satisfy client's needs subject to constraints.
Outcome D:	Team work and Deliverables: Ability to work in teams and understand the effective team dynamics and be able to deliver a product.
Outcome E:	Problem Solving: Ability to apply relevant scientific and engineering principles to solve real world engineering problems.
Outcome F:	Professional Practice and Ethics: Sound understanding of what a Materials professional is, and an awareness and understanding of professional ethics.
Outcome G:	Communication: Ability to communicate effectively in oral, written and visual forms.
Outcome H:	Contemporary issues, non-technical issues, global awareness: An awareness of contemporary and non-technical issues in engineering profession and the role of professionals in an interdependent global society.
Outcome I:	Life Long Learning: A facility for independent learning and continued professional development.

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

ENGINEERING PHYSICS (Micro-Nano)

Freshman Year

Fall Term		Credit
PH 111	Physics I	4
MA 111	Calculus I	5
CLSK 100	College & Life Skills	1
CHEM 111	General Chemistry I	4
EM 104	Graphical Communications	2
	Total	16

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

Spring Term		Credit
PH 113	Physics III	4
MA 113	Calculus III	5
ME 123	Computer Applications I	4
OE 172	Optics in Technology*	2
EM 103	Introduction to Design**	2
	Total	17*

Sophomore Year

Fall Term		Credit
ECE 203	DC Circuits	4
PH 235	Many Particle Physics	4
MA 211	Differential Equations	4
SEM	Sci, Engr or Math Elective	4
	Total	16

Winter Term		Credit
EP 280	Intro to Nano Engineering	4
PH 255	Foundations of Modern Physics	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
ECE 204	AC Circuits	4
	Total	16

Spring Term		Credit
EP 380	Nano Technology Entrepreneurship and Ethics	4
OE 295	Optical Systems	4
SV 151	Principles of Economics	4
EM 121	Statics	4
	Total	16

Junior Year

Fall Term		Credit
PH 316	Electric and Magnetic Fields	4
ENG	200 Level Engineering Elective	4
PH 405	Semiconductor Materials and Applications	4
MA 223	Engineering Statistics I	4
	Total	16

Senior Year

Fall Term		Credit
EP 416	Engineering Physics Project II	4
EP 407	Semiconductor Fabrication and Characterization	4
EP 411	Advanced MEMS	4
HSS	Elective	4
	Total	16

Winter Term		Credit

Winter Term		Credit
HSS	Elective	4
PH 317	Electromagnetism	4
RH 330	Technical and Professional Communication.	4
EP 406	Semiconductor Devices and Fabrication	4
	Total	16

Spring Term		Credit
PH 327	Thermodynamics & Stat Mech	4
EP 410	Intro to MEMS	4
EP 415	Engineering Physics Project I	4
HSS	Elective	4
	Total	16

EP 417	Engineering Physics Project III	4
ENG	300/400 Engineering Elective	4
HSS	Elective	4
PH 401	Intro Quantum Mechanics	4
	Total	16

Spring Term		Credit
HSS	Elective	4
HSS	Elective	4
ENG	Engineering Elective	4
Free	Free Elective	4
	Total	16
	Total credits required:	194

*If students miss OE 172 in the freshmen or sophomore year, this requirement must be replaced with a 300 or 400-level OE course of at least 2 credits.

EP course descriptions are listed under the Physics and Optical Engineering Department.

Courses taken in the respective departments:

Subjects	#Classes	Hours
Physics(PH)	10	40
Math(MA)	6	27
Chemistry(CHEM)	2	8
ME	1	4
EM	3	8
CLSK	1	1
Electrical Engineering	2	8
Optical Engineering (OE)	2	6
HSS	9	36
Engineering Physics (EP)	6	24
Engineering Physics Project(EP)	3	12
Elective(SEM, Eng. and Free)	5	20
Total	50	194

SUMMARY OF GRADUATION REQUIREMENTS FOR ENGINEERING PHYSICS

1. All the courses listed above by the number.
2. The program must be approved by the EP advisor.
3. A list1 0 l8e EP adC ET BT /T1_0 1 Tf 7.Tj 17.23(A list1 0 l8e EP adC ET /Span 3ad [(ided 0 l8e EP adC ET BT /T1_4 1 Tf 7.Tj 1_1 99 Science,6)]TJ -17.29, 7.299)

Total	193

Foundation Physics Classes

Course	Description	Hours
PH 235	Many Particle Physics	4
PH 255	Modern Physics	4
PH 316	Electric & Magnetic Fields	4
PH 317	Electromagnetism	4
PH 327	Thermodynamics and Statistical Mechanics	4
PH 401	Introduction to Quantum Mechanics	4
Total		24

General Foundation Classes

Course	Description	Hours
PH 111	Physics I	4
PH 112	Physics II	4
PH 113	Physics III	4
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 211	Differential Equations	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 223	Engineering Statistics	4
CHEM 111	General Chemistry I	4
CHEM 113	General Chemistry II	4
Total		47

Engineering Sciences Foundation

Course	Description	Hours
EM 104	Graphical Communications	2
OE 172	Lasers and Fiber Optics	2
EM 121	Statics I	4
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
EP 280	Introduction to Nano-engineering	4
EP 380	Nanotechnology, Entrepreneurship and Ethics	4
OE 295	Photonic Devices and Systems	4
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
EP 410	Introduction to MEMS; Fabrication and Applications	4
EP 411	Advance Topics in MEMS	4
EP 407	Semiconductor Fabrication % Characterization	4
	Engineering Elective	12
ME123	Computer Applications	4
Total		68

Design Sequence

Course	Description	Hours
EM 103	Introduction to Design	2
EP 415	Engineering Physics Projects I	4
EP 416	Engineering Physics Projects II	4
EP 417	Engineering Physics Projects III	4
Total		14

Approved Engineering 200-Level Electives (4 credit hours required)

ECE 205 Circuits and Systems

ES 201 Conservation and Accounting Principles

ES 202 Fluid and Thermal Systems
EM 204 Statics II
OE 280 Geometric Optics
EP 290 Directed Study
EP 490 Directed Study

Approved Engineering Electives

OE 360 Optical Materials
OE 393 Fiber Optics
OE 437 Introduction to Image Processing
OE 450 Laser Systems and Applications
OE 495 Optical Metrology
EP 330 Materials Failure
EP 470 Special Topics in Engineering Physics
EP 490 Directed Study
CHE 315 Materials Science and Engineering
ME 328 Materials Engineering
ME 417 Advanced materials Engineering
ME 422 Finite Elements for Engineering Applications
EM 403 Advanced Mechanics of Materials
ECE 351 Analog Electronics
ECE 250 Electronic Device Modeling

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International Computer Science

INTERNATIONAL COMPUTER SCIENCE

The International Computer Science curriculum prepares students for careers in all areas of the computer industry as well as for graduate studies in computer science and computer related fields. Students have also found a computer science major to be excellent preparation for careers in law, medicine, business administration, industrial engineering, biomedical engineering, and other technical and non-technical fields.

Computer science is a rapidly changing discipline. The lifetime of a particular computer system or software package can be very short. The international computer science curriculum is designed to prepare students for multiple careers in a rapidly changing, global environment. The program's courses emphasize fundamental concepts and techniques that will last longer than present technology.

International computer science majors complete a core of basic computer science courses that includes the study of algorithms, data structures, database concepts, computer systems, computer architecture, programming languages, operating systems, and software engineering. Advanced courses in theory of computation, computer networks, distributed systems, security, and real time systems add depth to the degree program. A three-term senior thesis provides students the opportunity to research in depth an area of computer science that is of interest to them under the mentorship of a faculty member. Majors also complete important courses in closely related fields, e.g., discrete mathematics and probability and statistics, as well as study a foreign language. The major requires students to study all aspects of the science of computing, including hardware, software, and theory.

Five free electives allow students to tailor their undergraduate education to their specific goals and pursue topics of interest to them. Students may choose to do advanced elective work in computer science and software engineering and/or in the humanities and social sciences, and/or pursue a minor or double major in another discipline.

Programming assignments and large projects are part of most computer science courses. These assignments familiarize students with the wide variety of tasks performed by software professionals. Programming assignments include system specification, system feasibility studies, system design, system maintenance studies, and user interface design in addition to system implementation (i.e., coding), testing (verification and validation), and documentation. Projects include both individual and team activities and require appropriate written and oral presentations.

The department has its own local area network. This network is connected to the campus-wide network and the Internet. Department laboratories provide docking stations and large screen monitors for students to attach their laptops to. International computer science majors have unlimited access to the department's laboratories.

The department has active programming teams that compete in the ACM Programming Contest and the Collegiate Cyber Defense Competition. The national computer science honor society, Upsilon Pi Epsilon, has chartered its Indiana Alpha Chapter at Rose-Hulman; it sponsors several seminars throughout the year.

International Computer Science Program Educational Objectives

Graduates from the international computer science program will be prepared for many types of careers in the

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

Additional Programs of Study

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

computing industry and prepared for graduate study in computer science and in closely related disciplines. In the early phases of their careers, we expect Rose-Hulman international computer science graduates to be:

1. Graduate students and researchers.
2. Leaders in government and law as government employees, policy makers, governmental advisors, and legal professionals.
3. Entrepreneurial leaders.
4. Business and technological leaders within existing organizations.
5. Actively involved in social and professional service locally, nationally, and globally.
6. Recognized by their peers and superiors for their communication, teamwork, and leadership skills.
7. Software professionals in a variety of organizations, including ones doing traditional software development, technological innovation, and cross-disciplinary work.

International Computer Science Student Outcomes

By the time students graduate with an international computer science degree from Rose-Hulman, they will be able to:

1. Effectively apply a variety of programming languages, programming paradigms, operating systems, networks, and software development tools.
2. Anticipate complexities and problems involved in the development of large software systems.
3. Analyze requirements, design software that satisfies those requirements, and implement that software.
4. Analyze problems using ideas of problem complexity, models of computation, and decidability.
5. Design algorithms using a variety of paradigms.
6. Analyze algorithms in terms of correctness as well as time and space efficiency.
7. Communicate effectively, both verbally and in writing.
8. Evaluate and discuss the legal, social, and ethical aspects of significant events that arise in the computing industry.
9. Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering.
10. Collaborate effectively in small teams.
11. Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering.
12. Explain the impact of globalization on computing and software engineering.
13. Recognize the need for, and engage in, lifelong learning.
14. Identify scalable solutions to problems and analyze the scalability of existing solutions under a variety of constraints.

The faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric and Composition	4
CLSK 100	College and Life Skills	1
	Total	18

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

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
GE 111	German Language and Culture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete and Combinatorial Algebra I	4
	Total	16

Winter Term		Credit
CSSE 230	Data Structures and Algorithm Analysis	4
GE 112	German Language and Culture II	4
MA 375	Discrete and Combinatorial Algebra II	4

VSYS, Technical German.

2. Four credits of science electives, which can be any CHEM, PH, AB, or GEOL courses not already required for the international computer science major.
3. Eight additional credits of technical electives. Consisting of any courses in biology, chemistry, engineering (except software engineering and engineering management), geology, mathematics, or physics.
4. Twelve credits of additional courses offered by the Department of Humanities and Social Sciences and/or appropriate humanities or social science courses offered at Hochschule Ulm. The distribution of these courses must meet the requirements of the Department of Humanities and Social Sciences at Rose-Hulman.
5. Twenty credits of free elective courses. These courses must have the approval of the student's academic adviser. Free electives may be selected from any Rose-Hulman course.
6. A total of 192 credits.

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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

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 h the major.

Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 330	Vector Calculus	4 hrs.
MA 336	Boundary Value Problems	4 hrs.
MA 433	Numerical Analysis	4 hrs.

Discrete Applied Mathematics Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

MA 375	Discrete and Combinatorial Algebra II	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the following		4 hrs.
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	

Statistics and Operations Research Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

MA 382	Introduction to Statistics with Probability	4 hrs.
MA 444	Deterministic Models in Operations Research	4 hrs.
One of the Following		4 hrs.
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Introduction to Mathematical Statistics	
MA 485	Applied Regression Analysis and Introduction to Time Series	
MA 487	Design of Experiments	

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives 12 hrs.

Additional mathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 excepted).

MA 190 – Contemporary Mathematical Problems (2 hrs.) A student taking a degree program in which mathematics is the primary major must also take MA 190. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Senior Project or Thesis (8 hrs.) A student must complete either a Senior Project, equivalent to the 8 credit hours of MA 491 – 494, or a Senior Thesis, equivalent to the 8 credit hours of MA 496 – 498. The project and thesis are each important capstone experiences for the mathematics major, representing sustained efforts to solve a complex problem from industry, mathematics modeling or application, or mathematical research.

Senior Project Option: Students seeking to do a senior project must complete a written project involving effort equivalent to the 8 credit hours of MA491 – 494. Specifically,

- MA 493 and MA 494 must be taken in seC 7.i -2.367 1.5 Toix e4 345.-2092(CombinatBT 092must complete a writtf9Fe 0 0Sl y(em axs 6 se(us7.e, rslfill)Tj Er

MA	Elective	4
	Technical Elective	
HSS	Elective	
	or	4
RH 330	Technical and Professional Communication	
	Total	16

Spring Term		Credit
MA	Elective	4

cr.), ME 123
- CSSE 132, ECE233, or ME430 - Introduction to Computer Systems, Introduction to Digital Systems, or Mechatronic Systems
- MA 332 (2) Introduction to Computational Science, or any of CE 310 (plus 2 cr.) CHE 310, ME 323(plus 2 Credits)

Advanced (20 credit hours; these courses may not be counted toward any other major or minor)

- CSSE/MA 335 Introduction to Parallel Computing
- MA 336 Boundary Value Problems
- MA 342 Computational Modeling
- MA 435 or ME 422 Finite Difference Methods, Finite Element Methods for Engineering Applications
- Any upper-level computational science course (see list below)

List of Advanced Electives

- BE 510 Biomedical Signal and Image Processing
- CHE 521 Advanced Chemical Engineering Computation
- CSSE 304 Programming Language Concepts
- ECE 480/PH 437 Introduction to Image Processing
- ECE 483 DSP System Design
- ECE 582/PH 537 Advanced Image Processing
- EMGT 526 Technology Forecasting
- EMGT 534/MA 534 Management Science
- MA 323 Geometric Modeling
- MA 348 Continuous Optimization
- MA 433 Numerical Analysis
- MA 434 Topics in Numerical Analysis

- 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

- 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

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.

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Since mechanical engineering is a broad field of endeavor, the curriculum offers a strong technical elective program to allow each student to craft a broad educational experience and to develop the flexibility to pursue diverse career goals.

No less than any professional, the mechanical engineering graduate must work within the social and environmental context of our world. To be effective and successful, he or she must be aware of the roles of engineering and science in solving complex technological and social problems as well as of the impacts of social and environmental factors on engineering activities such as design. To foster this awareness, the curriculum allows the student an unusually wide choice of social science and humanities electives and emphasizes the links between society and engineering through courses such as Engineering Design Processes and Methodology.

The strength of any department is its faculty. The mechanical engineering faculty is committed to providing a dynamic and innovative learning environment and to maintaining and increasing their technical competence in a rapidly changing world. Stereotypes notwithstanding, they understand that people are more important than things. Thus, they encourage each student to seek them out when he or she has academic problems or needs guidance in career planning.

The freshman year of the mechanical engineering program includes courses in mathematics, physics, humanities and social science as well as introductory courses in engineering and design. The sophomore year features courses in mathematics, chemistry and the engineering sciences. The final two years of the program stress the design and analysis of systems, machines and their components, and the transfer and transformation of energy. The required courses provide the basic mathematical and scientific fundamentals underlying the practice of mechanical engineering, while 20 cr. hrs. of technical elective courses and 8 cr. hrs. of free elective courses allow flexibility in adapting the program to the interests and abilities of the individual student. The student is not encouraged to specialize in a particular area but rather to seek a broad background in basic engineering principles. For the student who wishes to pursue a career in the field of aerospace engineering, however, extensive sequences of courses are available as elective offerings.

The mechanical engineering program is designed to encourage the best students to continue their education at the graduate level. For those who choose to study at Rose-Hulman, graduate work leading to a Master of Science degree is offered by the Mechanical Engineering Department. Options in the general areas of Thermal/Fluids Systems and Solid Systems Design are available. These options are devoted to developing a deeper understanding of engineering and are not intended to constrain the student to a high degree of specialization.

Mission: To provide the curriculum, the educational environment, and the individual support necessary to graduate mechanical engineers who are technically competent, effective in practice, creative, ethical and mindful of their responsibility to society.

Vision: To graduate the best baccalaureate mechanical engineers.

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

Additional Programs of Study

- Air Force ROTC (Military)
- Biochemistry & Molecular Biology (Second Major .906 Td ( )Tj EMC ET BT 7.6931d ( )Tj EMC ry

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Mechanical Engineering Program Educational Objectives and Student Outcomes

Program Educational Objectives

The mechanical engineering curriculum is designed to prepare students for productive careers in industry, government, education, and private consulting as well as for graduate study. Thus, it is based on the fundamental principles of science and engineering. These provide a strong foundation that enables students to apply what they have learned to the complex technological problems of today and to teach themselves the new technologies of tomorrow. Thus, we expect our graduates to attain the educational objectives listed below within a few years of graduation. Our educational objectives are based on the needs of our constituencies.

1. Our graduates will be successful in their careers.
2. Our graduates set and meet their own goals for career fulfillment.
3. Our graduates will continue professional development.
4. Our graduates will engage the international dimensions of their profession.

Student Outcomes

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.

a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multi-disciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Area Minor*** in Thermal-Fluids

To complete the requirements of the thermal-fluids area minor, a student must fulfill the following three expectations:

(1) Completion of a set of 2 courses covering basic fluid mechanics and basic thermodynamics. These are commonly required for most engineering majors. Acceptable sets include:

- ES 201 Conservation & Accounting Principles
  ES 202 Fluid & Thermal Systems
  or
- ME 201 Thermodynamics

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 HaC3umanke.eiocstriSes concentrat ttakef3 CID TT0 1 Tf 7.1sder /oncecpwye-catalog/couMedgeering Math Magement, and
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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 Econmoics
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

Freshman Year

Fall Term		Credit
MA 111	Calculus I	5
PH 111	Physics I	4
CLSK 100	College & Life Skills	1
EM 104	Graphical Communications	2
RH 131	Rhetoric and Composition split fall or winter with Elective	4
HSS		
	Total	16

Winter Term		Credit
MA 112	Calculus II	5
PH 112	Physics II	4
EM 121	Statics and Mechanics of Materials I	4
RH 131	Rhetoric and Composition split fall or winter with Elective	4
HSS		
	Total	17

Spring Term		Credit
MA 113	Calculus III	5
PH 113	Physics III	4
EM 103	Introduction to Design	2
ME 123	Computer Applications I	4
	Total	15

Junior Year

Fall Term		Credit
ME 301	Thermodynamics II	4
EM 204	Statics & Mechanics of Materials	4
ME406 or EM 406	Control Systems or Vibration Analysis	4
*Free	Elective	4
	Total	16

The science of light, once confined to research labs and science fiction novels, has found its way into our everyday lives. The applications of optics can be seen everywhere. A list of more common examples of these applications include laser printers, fiber optic communication, internet switches, fiber optic telephone lines, compact disc players, credit cards bearing holograms, grocery checkout scanners, computers and eye surgery. The field of optics is an enabling technology and is growing at a rapid pace. Optical techniques are found in a wide range of areas such as surveying and construction, measurements of material parameters and deformation, flow measurements, communications, machine vision, laser cutting, drilling and welding, data storage, internet switches, optical computers and sensors etc. Surveys show that there is a growing demand for optical designers/scientists/ engineers every year. Opportunities for graduates in Optical Engineering are available in many industries, including automated inspection, consumer electronics, fiber optic communications, optical instrumentation, laser devices, radar systems, data storage etc.

The Optical Engineering bachelor's degree program is one of the few in the country. This program provides a firm foundation for those interested in continuing thier studies in optics at the graduate level, as well as for those going into industry. The curriculum was developed by the faculty with input from industrial representatives as well as from renowned national and international optics educators. Because of the diverse applications of optics, the curriculum contains a mix of courses in physics and mathematics as well as humanities and social sciences. The Optical Engineering program at Rose-Hulman stresses laboratory instruction. We also encourage students to look at options for a double major, especially Optical Engineering with electrical, computer or mechanical engineering.

Students majoring in degree programs other than Optical Engineering are eligible to obtain an area minor in Optical Engineering.

The Department of Physics and Optical Engineering also offers an M.S. (Optical Engineering) degree. The masters level degree program complements the B.S. (Optical Engineering) degree program. Highly motivated students may obtain both a B.S. and an M.S. in Optical Engineering in a five-year period. A plan of study for this program must be approved by the end of the student's junior year.

You may view all information regarding Physics and Optical Engineering at our web site: http://www.rose-hulman.edu/physics.aspx

- Demonstrate competency in applying knowledge of mathematics (such as multivariable calculus, differential equations, linear algebra, complex variables, and probability and statistics), physics and chemistry
- Demonstrate competency in applying basic engineering science topics with common themes among engineering disciplines
- Demonstrate competency in applying theoretical and experimental knowledge in geometrical optics, physical optics, optical materials and devices to modeling, analysis and design of optical/photonic devices and systems

Outcome B:

An ability to design and conduct experiments, as well as to analyze and interpret data

- Identify the problem and determine what data need to be collected.
- Apply safe laboratory practices
- Select appropriate measurement techniques to collect the data.
- Demonstrate the ability to use laboratory equipment for measurement.
- Use appropriate statistical and analytical procedures to estimate uncertainties and interpret results
- Be able to recognize the necessity to use graphical and numerical analysis
- Extract trends and demonstrate their importance from numerical data, graphs, and text.
- Draw conclusions

Outcome C:

An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

- Elicit customer needs and define realistic constraints
- Identify viable alternatives in design and make an informed selection.
- Break down a system/process to its fundamental elements and components.
- Carry out design using appropriate tools.
- Incorporate economic analysis and analyze cost in design.
- Apply appropriate engineering standards.
- Deliver a functional prototype that meets customer needs.
- Document project work and give an oral and formal written report.

Outcome D:

An ability to function on multidisciplinary teams

-

PH292	Physical Optics	4
PH316	Elec & Mag Fields	4
PH405	Semiconductor Materials & Applications	4
Total		20

Freshman Physics, Math and Chemistry Classes

Course	Description	Hours
PH111	Physics I	4
PH112	Physics II	4
PH113	Physics III	4
MA111	Calculus I	5
MA112	Calculus II	5
MA113	Calculus III	5
MA211	Differential Equations	4
MA212	Matrix Algebra and Systems of Differential Equations	4
MA223	Engineering Statistics	4
CHEM111	Engineering Chemistry I	4
CHEM113	Engineering Chemistry II	4
Total		47

Miscellaneous and Engineering Classes

Course	Description	Hours
CLSK 100	College and Life Skills	1
EM 104	Graphical Communication	2
ME 123	Computer Applications I	4
EM 103	Introduction to Design	2
ECE 203	DC Circuits	4
ECE 204	AC Circuits	4
Total		17

Area Minor

The course requirements and advisors for Area Minors in Optical Engineering, Solid State Physics/Materials

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 or HSS	Rhetoric and Comp or HSS Elective	4
EM 104	Graphical Communications	2
	Total	16

Winter Term		Credit
PH 112	Physics II	4
MA 112	Calculus II	5
CHEM 111	General Chemistry I	4
	Computing Elective*	2-4
	Total	15 or 17

Spring Term		Credit

Sophomore Year

Fall Term		Credit
	Free Elective†	4
PH 235	Many Particle Physics	4

PH 113	Physics III	4
MA 113	Calculus III	5
CHEM 113	General Chemistry II	4
HSS or RH131	HSS Elective or Rhetoric and Composition	

9. A free elective is any course offered at RHIT.

Course by Subjects

† A maximum of 4 credit hours total from PH270/470, PH290/490, and PH460 may be counted towards the area minor.

*Students majoring in Optical Engineering may not count PH292 for the minor requirements. Such students may substitute here any PH course numbered 300 or greater which is not a named requirement for the OE major.

**ECE340 may be substituted here for students who take it as part of their major degree requirements.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your official transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Astronomy
Eligibility: Students in any major degree program

Advisors: Drs. Ditteon, Duree, Kirkpatrick, McInerney and Syed

Required Courses

Course	Course Title	Hours
PH 231	Observational Astronomy	2
PH 241	Physics of Stars	4
PH 250	Planets and Galaxies	4

It is recommended, but not required, that the required courses be taken in the order listed above.

Plus eight hours of:

PH 270	Special Topics in Physics	2
PH 310	Introduction to Special Relativity	2
PH 322	Celestial Mechanics	4
PH 410	General Relativity	4
PH 460	Directed Study	1
PH 470	Special Topics in Physics	2
PH 290/490	Directed Research	1

The optional courses must be on a topic approved by one of the astronomy advisors.

Normally, only one credit of directed research or directed study is taken each quarter. Directed study and directed research may be repeated (4 hours maximum) and must be on a topic approved by one of the astronomy advisors.

In order to have the area minor posted to your transcript you must submit an area minor completion form to the registrar. Forms are available in the Physics and Optical Engineering office.

Area Minor in Solid State Physics/Materials Science
Eligibility: Students in any degree program, except students who are working for the Semiconductor Materials and Devices Certificate.

Advisors: Dr. Bunch, Dr. McInerney, Dr. Moloney, Dr. Siahmakoun, Dr. Syed, Dr. Wagner

Required courses:

Course	Description	Hours
PH 405	Semiconductor Materials and Applications	4
EP 406	Semiconductor Devices and Fabrication	4
ME 328/CHE 315	Materials Engineering/Material Science & Engineering	4

Plus at least two of:

Course	Description	Hours

OE 360	Opto-mechanics and Optical Materials	4
EP 330	Material Failure	4
PH 407	Solid State Physics	4
EP 408	Microsensors	4
PH 440	X-Rays and Crystalline Materials	4
PH 490/ME 490	Directed Research	4
ME 408	Heat Transfer	4
ME 417	Advanced Materials Engineering	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in Optical Engineering
Eligibility: Students in any degree program, except Optical Engineering.

Advisors: Drs. Bunch, Ditteon, Duree, Granieri, Joenathan, Lepkowicz, Siahmakoun, Wagner, F. Berry, and Black.

Required courses:

Course	Description	Hours
OE 280	Paraxial Optics	4
PH 292	Physical Optics	4
OE 295	Optical Systems	4

Plus at least two* courses from one of the areas listed below:

Lens Design Area

OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 480	Lens Design and Aberrations	4
OE 490	Directed Research (4 Credits Only)	4

Photonics/Electro-optics Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	4
OE 415	Optical Engineering Design I	4
OE 450	Laser Systems and Applications	4
OE 485	Electro-optics and Applications	4
OE 490	Directed Research (4 Credits Only)	4
OE 493	Fundamentals of Optical Fiber Communications	4

Image Processing Area

Course	Description	Hours
OE 360	Optical Materials and Opto-mechanics	
OE 415	Optical Engineering Design I	4
OE 490	Directed Research (4 Credits Only)	4
OE 437/ECE 480	Introduction to Image Processing	4
PH 537/ECE 582	Advanced Image Processing	4

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Physics and Optical Engineering Departmental Office, CL106.

Area Minor in ECE
Eligibility: Only students in Physics and Optical Engineering

Advisors: Physics and Optical Engineering faculty and Electrical and Computer Engineering faculty

Course Number	Course Title	Credits
ECE 203 Required	DC Circuits	4
ECE 204 Required	AC Circuits	4

ECE 205	Dynamical Systems	4
ECE 300	Continuous-Time Signals and Systems	4
ECE 310	Communication Systems	4
ECE 380	Discrete-Time Signals and Systems	4

To see the complete list of optional courses available for this minor, please see the Electrical and Computer Engineering Department Area Minor Listing. Taking courses other than the ones listed here may require the student to take additional courses to fulfill the prerequisites for the other courses.

An Area Minor Completion Form must be submitted to the Registrar's Office in order for the Area Minor to be posted on your Official Transcript. The forms are available in the Electrical and Computer Engineering Departmental Office.

Also see Certificate Program in Semiconductor Materials and Devices

You may view all information regarding Physics and Optical Engineering at our web site: http://www.rose-hulman.edu/physics.aspx

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812-877-1511

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throughout the year. The national honor society in the computing and engineering disciplines, Upsilon Pi Epsilon and Tau Beta Pi, both have chapters at Rose-Hulman. Software engineering majors are also eligible to join the Order of the Engineer, which focuses on the ethical and professional responsibilities of an engineer, during the spring of their last year of study.

Software Engineering Program Educational Objectives

The software engineering program prepares its graduates for many types of careers in the computing industry as well as for graduate study in software engineering and in closely related disciplines. Within a few years after completing the software engineering degree program, our graduates will:

- Advance beyond their entry-level position to more responsible roles, or progress towards completion of advanced degree(s).
- Continue to keep pace with advancements in their disciplines, and develop professionally in response to changes in roles and responsibilities.
- Demonstrate that they can collaborate professionally within or outside of their disciplines at local, regional, national, or international levels.
- Contribute to the body of computing products, services, or knowledge.

Software Engineering Student Outcomes
By the time students graduate with a Software Engineering degree from Rose-Hulman, they will be able to:

- Apply software engineering theory, principles, tools and processes, as well as the theory and principles of computer science and mathematics, to the development and maintenance of complex, scalable software systems.
- Design and experiment with software prototypes
- Select and use software metrics
- Participate productively on software project teams involving students from a variety of disciplines
- Communicate effectively through oral and written reports, and software documentation
- Elicit, analyze and specify software requirements through a productive working relationship with project stakeholders
- Evaluate the business and impact of potential solutions to software engineering problems in a global society, using their knowledge of contemporary issues
- Explain the impact of globalization on computing and software engineering
- Interact professionally with colleagues or clients located abroad and overcome challenges that arise from geographic distance, cultural differences, and multiple languages in the context of computing and software engineering
- Apply appropriate codes of ethics and professional conduct to the solution of software engineering problems
- Identify resources for determining legal and ethical practices in other countries as they apply to computing and software engineering
- Recognize the need for, and engage in, lifelong learning
- Demonstrate software engineering application domain knowledge

The Computer Science and Software Engineering faculty strives to maintain an open atmosphere that encourages mutual respect and support as well as learning and sharing of knowledge.

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

SOFTWARE ENGINEERING

Freshman Year

Fall Term		Credit
CSSE 120	Introduction to Software Development	4
MA 111	Calculus I	5
PH 111	Physics I	4
RH 131	Rhetoric & Composition	4
CLSK 100	College and Life Skills	1
	Total	18

Winter Term	Credit

Sophomore Year

Fall Term		Credit
CHEM 111	General Chemistry I	4
CSSE 232	Computer Architecture I	4
MA 212	Matrix Algebra and Systems of Differential Equations	4
MA 275	Discrete & Combinatorial Algebra I	4
	Total	16

AREAS OF STUDY

Global Studies Ideas and Art Society and Values Modern Languages

MAJORS

- Economics
- International Studies (second major only)

GERMAN TECHNICAL TRANSLATION CERTIFICATE

MINORS

Anthropology Art East Asian Studies Economics European Studies Geography
German

disciplines analyze the ideas and expressive artifacts of individuals or groups emphasizing qualitative rather than quantitative methods. The Humanities provide us with the broad frameworks within which enduring questions of existence, relationships, values, and aesthetics can be examined from multiple perspectives.

The SOCIAL SCIENCES study human interactions and the social institutions in which these occur. These disciplines tend to adopt scientific methods, emphasizing quantitative rather than qualitative approaches. The Social Sciences provide us with the broad frameworks within which to analyze the nature of social systems, processes, and outcomes.

The following disciplines are represented within the department:

HUMANITIES	SOCIAL SCIENCES
Art and Art History	Anthropology
English and Literature	Archaeology
Foreign Languages(German, Japanese, and Spanish)	Economics
History	Geography
Music	Political Science
Philosophy and Religion	Psychology
Theater	Sociology

Thematic Categories

The majority of courses offered by the department are distributed across three thematic categories. These are:

- Global Studies (GS prefix): Courses whose primary focus is on the examination of other societies, or on the interrelationships among multiple societies.
- Ideas and Arts (IA prefix):

Aptitude Test (SAT) or of 34 or above on the English section of the ACT exam.

2. Has received grades of B or higher in all high school English courses.

- INTERNATIONAL STUDENTS: International students for whom English is not their native language will be required to take an assessment test to gauge their written, oral, and listening proficiency in English. The purpose of this testing is to ensure that all students have the proper communication skills to advance successfully through the challenging Rose-Hulman curriculum. Based on this assessment, some students will be required to take CLSK121 College English. Those students must successfully complete CLSK121 prior to taking RH131 Rhetoric and Composition.

3. Technical and Professional Communication

- Technical and Professional Communication is a requirement for most majors. Students are required to take RH 330 on campus. Students who have taken a technical writing course at another college will be granted free elective transfer credit, but are not exempted from RH 330.

4. Distribution Requirements

- All students will take two courses in each of the three thematic categories: Global Studies, Ideas and Arts, and Society and Values. The section of course descriptions lists courses currently available in each category. Students are also required to take one additional course in any category OR two additional courses in any category IF Technical Communication is not required of any of the student's majors. Technical communication may be taken as one of the additional courses if not required by the student's major(s).

5. Foreign Language

- Students who elect to take a foreign language should note the following special requirements.

    1. A minimum of two terms of the same language (or the equivalent thereof) must be completed in order to apply foreign language credits toward Humanities and Social Sciences requirements. If only SP111, JP111 or GE111 is completed, that course will not be allowed to satisfy an HSS requirement."

    2. HSS credit will not be awarded for a lower-level language course until the student takes and passes the following course in the language sequence with a grade of C or better.

    3. Students who take 2-3 courses in a foreign language sequence may allocate those language

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	Paul Christensen
Art	Steve Letsinger
East Asian Studies	Tim Grose
Economics	Dale S. Bremmer
	Kevin Christ
	Jong Hun Kim
European Studies	Andreas Michel
German	Heidemarie Heeter
Geography	Michael Kukral
History	Samuel Martland
Japanese	Maki Hirotani

Introduces students to China's "official" religions (Buddhism, Taoism, Islam, Protestantism, and Catholicism) and the rich faith-based belief systems that are prominent in contemporary China (Shamanism, local deities, etc.). (NOTE: Formerly Asian Religions and Philosophy)

GS 221 Colonial Latin America 4R-OL-4C
Examines the history of Latin America from before the conquest to independence, with particular emphasis on social, economic, political, and cultural developments between 1492 and 1800.

GS 222 Modern Latin America 4R-OL-4C
Examines the history of Latin America from independence (about 1810) to the present, with particular emphasis on the social, economic, political, and cultural developments of the past hundred years. Introduces major problems facing contemporary Latin America, including the search for stable government, political violence, environmental degradation, and extreme poverty and inequality.

GS 223 World History since 1400 4R-OL-4C
Explores the history and interaction of major world regions since about 1400, with particular emphasis on the development of global economic, political, and cultural networks in recent centuries.

GS 231 Global Writing and Intercultural Communication 4R-OL-4C
Analyzes rhetorical traditions and communication styles within and across diverse cultures as well as global uses of English. Introduces students to theories and practices for communicating and collaborating across languages and cultures.

GS 237 Science Fiction 4R-OL-4C
Analyzes literary techniques used for displacing historical reality into a cross-cultural perspective to create science fiction. E 15.56i7o create
scnd collabint

GS 336 Literature of War 4R-OL-4C
Examines the influence of military engagements on individual writers. Analyzes literary works as responses to the cultural, psychological, and social impacts of war.

GS 337 Shakespeare's Europe 4R-OL-4C
Studies Shakespeare's representations of cultures outside of Britain, with attention to his source texts in other national literatures and historians' perspectives on the cities where the plays are set.

GS 338 Contemporary Arabic Literature in Translation 4R-OL-4C
Covers a range of literature and film by writers and filmmakers from North Africa, the Middle East, and the Arabic-speaking diaspora. Includes literature in translation by major authors of this genre and critical works by a number of scholars of Arabic literature.

GS 339 Contemporary Global Film 4R OL 4C
Surveys world cinema, emphasizing the importance of situating films within their historical and cultural background as well as recognizing the tensions between art and business in the film industry and how that shapes the medium.

GS 343 Musics of the World 4R OL 4C
Surveys the role of music in human cultures around the world and explores problems of accessing musical practices distant and distinct from our own, as well as thinking critically about those most familiar to us.

GS 350 International Trade and Globalization 4R-OL-4C Prereq: SV 150 or SV 151
Analyzes the theory of international trade, trade policy, foreign exchange and the payments adjustment process, adjustment policies and multinational corporations.

GS 351 International Finance 4R-OL-4C Prereq: SV 152 or SV 151
Studies the workings of international financial markets, the role of exchange rates in international trade and capital movement, and the effects of exchange rate volatility. Topics include exchange rates and the foreign exchange market, the balance of payments, parity conditions, the international monetary system, and international interdependence.

GS 352 Economic Growth and Development 4R-OL-4C Prereq: SV 151 or SV 152
Analyzes the determinants of economic growth. Pays special attention to problems faced by developing nations and discusses the impact of globalization.

GS 361 Politics of the Global Economy 4R-OL-4C
Analyzes the political aspects of the global economy. Reviews the dominant theoretical approaches, concepts, and major issues in the international political economy.

GS 366 The European Union 4R-OL-4C
Examines the historical development of European integration and current EU institutions, politics, and policy.

GS 368 Tokyo 4R-OL-4C
Explores Tokyo from its origins to contemporary place as a “global capital” through history, geography, and culture.

GS 379 Japanese Culture 4R-OL-4C
Examine Japanese culture in various aspects (e.g., society, arts, history, education, media, and pop culture).

GS 380 Pop Culture in China 4R-OL-4C
Examines the production and consumption of pop culture in China including literature, music, film, and print media.

GS 384 Japanese Society 4R-OL-4C
Introduces contemporary Japan from an anthropological perspective with an emphasis on the contradictions between hyper-modernity and traditionalism.

GS 386 Hispanic Culture and Civilization (Latin America) 4R-OL-4C Prerequisite: SP213 or permission of instructor
Introduces Hispanic culture and civilization from its origins to the present. Examines Hispanic Latin American societies through cultural expression, including literature, visual arts, music and film. Analyzes the diversity of cultural aspects of Spanish Latin America. Taught in Spanish.

GS 387 Hispanic Culture and Civilization (Spain) 4R-OL-4C Prerequisite: SP213 or permission of instructor
Introduces Hispanic culture and civilization from its origins to the present. Examines Spanish society through

anthropological perspective. Considers how Japan has been created and framed as a site of study through close readings of relevant ethnographic literature.

GS 491 Geography of Europe 4R-OL-4C
Introduces the culture, landscape, and peoples of Europe through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing the Europeans, from Russia to Ireland and all points between.

GS 492 Geography of Africa 4R-OL-4C
Introduces the culture, landscape, and peoples of Africa south of the Sahara Desert through discussion, maps, regional analysis, and visual presentations. Includes social issues and contemporary problems facing this area, from South Africa to Senegal and all points between.

GS 496 and GS497 Senior Project in International Studies (2 credits each; 4 credits total)
Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

GS CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

IDEAS AND ARTS -- Courses whose primary focus is on theories and debates within disciplines, the development of ideas, or arts and aesthetics.

IA 101 Introduction to Philosophy 4R OL 4C
Introduces the methods and subject matter of philosophy through examination of some of the major problems and figures in classical and contemporary philosophy, including the nature of reality, the existence of God, the criteria of knowing, the nature of mind, and the foundations of morality.

IA 102 Critical Thinking and Introduction to Logic 4R OL 4C
Introduces students to philosophical methodology for examining the truth of claims and the quality of arguments used to defend them, including informal logic, i.e., the study of arguments in natural language, as well as formal logic, i.e., the study of inference with purely formal content, for the purpose of clarifying thinking and improving reasoning.

IA 128 Introduction to Islam 4R-OL-4C
Introduces the major figures, tenets, and cultural adaptions of Islam from Muhammad to the present day.

IA 142 Drawing 4R-OL-4C
Introduces the student to drawing as a basis of personal expression. Exposes the student to a range of tools, techniques, and attitudes.

IA 148 Beginning Photography 4R-OL-4C
Introduces the student to historical aspects of photography, the impact of the visual image in modern culture, and photography as a medium of individual expression.

IA 230 Fundamentals of Public Speaking 4R-OL-4C
Examines the thought processes necessary to organize speech content. Analyzes components of effective delivery and language. Provides practice in a variety of speech types, such as special occasion speeches, informative presentations, and persuasive speeches, as well as impromptu speaking.

IA 231 Introduction to Poetry 4R-OL-4C
Provides students with the means for understanding and appreciating poetry. Focuses on tone, speaker, figurative language, verse forms, and structure in poems from a variety of historical periods.

IA 232 African American Music in American Literature 4R-OL-4C
Surveys the history of African-American music, from slavery to the present, and considers the ways in which writers have adapted different musical styles into their work. Includes--but is not limited to--readings on spirituals, blues, jazz, funk, and hip-hop; written works will include nonfiction, novels, poetry, short stories, and drama.

IA 233 World Literatures 4R-OL-4C
Examines literary texts and their historical contexts across boundaries of language, culture, and ethnicity.

IA 234 Major American Writers 4R-OL-4C
Covers a broad range of American novelists and poets, with special attention to their roles in major literary movements such as romanticism, naturalism, and modernism.

IA 235 Major British Writers 4R-OL-4C
Examines well-known British writers, placed against the historical backgrounds of their times. Poetry, drama, fiction, and non-fiction from such famous writers as Chaucer, Spenser, Shakespeare, Milton, Swift, Pope, Johnson, Wordsworth, Bronte, Browning, Joyce, Lawrence, Auden, and Beckett will be studied.

IA 236 Communicating STEM to a Public Audience 4R-OL-4C
Examines the role of scientists and engineers as public intellectuals who can influence policy and public understanding. Emphasizes strategies for communicating technical knowledge to public audiences through popular media.

IA 237 Introduction to Drama 4R-OL-4C
Traces the development of drama by analyzing representative plays from historical periods and from different cultures. Analyzes how, and why, drama has changed over time and how individual plays mirror their times and cultures.

IA 238 African American Literature 4R-OL-4C
Surveys African-American literature, history, and culture from the Colonial era to the present day.

IA 239 Rhetoric of Science

IA 311 Topics in German Culture I 4R-OL-4C
Examines a variety of historical and contemporary issues in German popular and high culture. Same as GE311.

IA 325 Islam and Muslim Groups in China 4R-OL-4C
Examines the localization of Islam among China's ten officially recognized Muslim ethno-national groups.

IA 328 Ethnicity & the State in China 4R-OL-4C
Introduces students to the concepts of ethnic group, ethnicity, and nationalism and explores how ethnonational identity is institutionalized, constructed, and negotiated in contemporary China.

IA 330 Documentary Film 3R-3L-4C
Examines the development, contexts, generic conventions, and social functions of documentary film

IA 331 American Modernism 4R-OL-4C
Explores texts published in the first half of the twentieth century, what is commonly called the "Modernist" era. Focuses primarily on written works in different genres, but also covers music, film, visual arts, and other media.

IA 332 Don Quixote 4R-OL-4C
Studies Cervantes' masterwork in translation and its relationship to the society and literature of its day as well as its relevance to our own. Taught in English.

IA 333 Representations and Redefinitions of Reality 4R-OL-4C
Examines representative pieces of philosophy, literature, and popular culture that all seek to represent and--in some cases--redefine the notion of "reality."

IA 334 Creative Writing 4R-OL-4C
Introduces students to writing in genres such as poetry, short fiction, literary nonfiction, and drama. Employs a variety of writing and revision techniques to assist students in producing a portfolio of their work.

IA 335 Bible as Literature 4R-OL-4C
Examines the Hebrew Bible and the New Testament as literary texts. Emphasizes the variety of genres employed in biblical literature and introduces students to different approaches appropriate to literary interpretation.

IA 336 Mystery & Horror Literature 4R-OL-4C
Examines the development, contexts, generic conventions, and social functions of modern horror and detective fiction from their roots in European Gothic traditions to the present.

IA 337 European Romanticism 4R-OL-4C
Covers major authors and themes in European Romantic literature from 1770-1830, as well as its repercussions and transformations.

IA 338 Medicine in Literature 4R-OL-4C
Examines images of patients, doctors, and other medical professionals as constructed in literary works. Explores medical and ethical issues as represented in both classic and current fiction.

IA 339 Rebellion in American Literature 4R-OL-4C
Examines American literary and historical texts that use rebellion against different kinds of authority--governmental, social, cultural, artistic, personal--as their central subject, motif, and / or theme. Includes readings from the Colonial era to the present day.

IA 340 Ethics in Human Communication 4R-OL-4C
Examines the interconnection between ethics and rhetoric by studying such topics as persuasion versus propaganda, manipulation and distortion through language, leadership and communication, manifestations of prejudice (racism and sexism), language of intimidation and oppression, dehumanizing communication, effects of advertisement, and the content and effectiveness of professional codes for ethical communication.

IA 342 Modern Southern Fiction 4R 0L 4C
Examines the major writers of the American South (both the modern and contemporary periods). Emphasizes recurrent social themes and fictional methods.

IA 343 Visual Rhetoric and Graphic Novels 4R-OL-4C
Explores the relationships between art and argument in comic books and graphic novels. Provides a vocabulary for students to discuss, analyze, and produce graphic communication, including the creation of their own mini-comic. (No drawing skills required).

IA 344 Writing in a Digital Age 4R-OL-4C

society, religion, government, the economy, and the impact of science and technology on daily life.

SV 231 Introduction to Short Fiction 4R-OL-4C
Guides students in reading, appreciating, and analyzing a range of short fiction. Gives special attention to how reading such fiction can help us better understand ourselves and our relationships to the societies in which we live.

SV 232 Introduction to Non-Fiction 4R-OL-4C
Guides students in learning about human interactions by reading, appreciating, and analyzing contemporary non-fiction works. Includes both general essays and science and nature writing.

SV 233 Survey of American Lit 4R-OL-4C
Studies a broad range of American literature since the Civil War. Examines a variety of authors and genres (fiction, poetry, prose, nonfiction).

SV 234 The American Dream 4R-OL-4C
Analyzes representations of the American Dream in fictional and non-fictional narratives through a cultural studies approach.

SV 242 Visual Arts in Civilization 4R-OL-4C
Investigates the purposes and uses of art in civilizations with an emphasis on art appreciation. Aesthetic and historical issues are explored to reveal how art makes worldviews tangible.

SV244 Western Music in the Baroque, Classical, Romantic Eras 4R-0L-4C
Surveys composers, events, and genres of western art music in the “common practice period” and their contexts in world historyl War. Examines a variety of authors and genres

GE 313 Advanced Grammar and Translation Methods 4R-OL-4C S Prereq: GE 312
Introduces advanced grammar concepts targeted for translation of German texts. Familiarizes students with translation techniques for a variety of text types.

JP 311/312/313 Japanese Language and Culture VII/VIII/IX (Through Study Abroad Program) 4R-XL-4C Summer Prereq: Preceding course
Further develops reading, writing, and speaking skills. Students learn technical terms by participating in engineering laboratory with Japanese students. Includes cultural field trips and company visits. [This course is offered as a summer program at Kanazawa Institute of Technology.]

GE 411 Technical Translation 4R-OL-4C F Prereq: GE 313
Introduces scientific and technological vocabulary; continues working with complex grammatical structures; applies methods of translation using scientific and technical texts. Requires the writing of a major technical translation project.

GE 412 Topics in German Culture II 4R-OL-4C W
Explores topics in German and European intellectual history as represented in literature, essay, and film. Same as GS 412.

GE 413 Contemporary Germany 4R-0L-4C S
Introduces historical, political, and cultural issues in German society from 1945 to the present. Compares German to European developments. Taught in English and open to all students. Same as SV 413.

JP 411/412/413 Japanese Language and Culture X/XI/XII (Through Study Abroad Program)

of people, or other actors
   B. Argue for a course of action—political, economic, or otherwise—when given an international situation/case study
3. Independent Study of global issues requires the application of appropriate analytic vocabulary, methodologies, or critical frameworks from the Humanities or the Social Sciences
   A. Assemble and evaluate resources for research in international studies.
   B. Design and carry out a research project analyzing a significant international or global issue, system, process, or event.

Requirements for a second major in International Studies (60 cred.)

- Students double majoring in International Studies may use their International Studies courses to satisfy HSS graduation requirements.
- Courses counted for the International Studies major may not be counted for HSS minors—except that foreign language courses may be used to fulfill foreign language requirements in one additional minor.
- Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.
- All International Studies majors are subject to approval by HSS Department Head and the Institute Curriculum Committee.

I. International Studies Core (24 cred.)

IA233	World Literature
GS163	International Relations
GS285	Humans and Culture
GS291	World Geography
SV150 OR SV152	Introduction to Microeconomics/Macroeconomics
GS223	World History since 1400

II. Area of Concentration (20 cred.)

Students choose 5 courses from one of three areas of concentration: (a) International Political Economy; (b) Comparative Cultures; or (c) Individualized IS Major.

a. International Political Economy: This concentration emphasizes the political, economic, geographic, and historical analysis of international relations.

Students must choose at least three courses from the general list and a total of five courses from both lists. Substitutions may be made with the approval of the IS advisor.

General List

IA353	History of Economic Thought
GS322	Industrial Revolution in a Global Context
GS350	International Trade and Globalization
GS351	International Finance
GS352	Economic Growth and Development
GS361	Politics of the Global Economy
SV328	Comparative Business History
SV354	Environmental Economics

Regional List

GS128	Introduction to East Asia
GS161	Comparative Politics
GS222	Modern Latin American
GS366	European Union
GS363	European Politics and Government
GS399	Geography of the Middle East
GS492	Geography of Africa

Reminder: Students wishing to pursue a double major in Economics and International Studies may not choose the IPE area of concentration.

a. Comparative Cultures: This concentration emphasizes the comparative study of institutions and traditions across and within nations and geographic regions.

Students must choose three courses from the general list and two from the regional list to ensure both breadth of analysis and depth of content. Substitutions may be made with the approval of the IS advisor.

General list

GS322 Industrial Revolution in Global Context
GS333 Travel in World Literature
GS334 Global Novel in the 20th Century
GS432 Literature of the Global Economy
GS462 Postcolonial Literature
SV191 Cultural Geography
SV201 Religion and Ecology

Regional list (including but not limited to the following courses)

IA311 Topics in German Culture I
GS128 Introduction to East Asia

GS222 Modern Latin America
GS313 Contemporary Spain
GS327 Modern China
GS335 Arabic Literature
GS379 Japanese Culture
GS391 Contemporary Europe
GS442 Art History: Reniassance to Modern
GS492 Geography of Africa

1. Individualized Major: Focus and composition of this concentration are to be designed by the student and approved by IS advisor and Department Head. It is the student's responsibility to present a coherent program of study focused on the international relations between peoples and cultures in the contemporary world.

Students must take a total of five courses.

III. One full year of a foreign language (e.g., German, Japanese, Spanish) (12 cred.)

IV. GS 496 and GS 497 Senior Project in International Studies (2 credits each; 4 credits total)

Guided study, research, and analytical writing on a topic in international studies, integrating knowledge gained from international experience and/or from course work in the major.

HSS MINORS

MINOR IN ANTHROPOLOGY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Anthropology has the following requirements:

1. Five Courses in Anthropology
2. The following course is required:
    - GS 185 Introduction to Anthropology
3. Four additional courses from the list below:
    - GS 128 Introduction to East Asia
    - GS 368 Tokyo
    - GS 379 Japanese Popular Culture
    - GS 384 Japanese Society
    - GS 385 Japanese Society Seminar
    - IA 388 Food, Culture, and the Self
    - IA 399 Anthropology of Addiction
    - SV 386 Human Evolution
    - SV 399 Anthropology of Sports
    - XX 399 Special Topics

- GS350 International Trade and Globalization
- GS351 International Finance
- GS352 Economic Growth and Development
- IA350 Intermediate Microeconomics
- IA351 Intermediate Macroeconomics
- IA352 Game Theory
- IA353 History of Economic Thought
- IA450 Mathematical Economics
- IA453 The Entrepreneur
- SV150 Introduction to Microeconomics
- SV152 Introduction to Macroeconomics
- SV351 Managerial Economics
- SV352 Money and Banking
- SV353 Industrial Organization
- SV354 Environmental Economics
- SV355 Health Economics
- SV356 Corporate Finance
- SV357 Labor Economics
- SV450 Econometrics
- XX399 Special Topics
- XX456/457 Senior Project

MINOR IN EUROPEAN STUDIES

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in European Studies has the following requirements:

1. Three courses (or proficiency) in either German or Spanish. (Language courses may be allocated in any of the four thematic categories, but there may be no more than one language course in any category.)
2. Four courses selected from the following:
    - GS313 Contemporary Spain
    - GS337 Shakespeare's Europe
    - GS363 European Politics and Government
    - GS366 The European Union
    - GS431 Literary London
    - GS469 Contemporary British Fiction and Film
    - GS491 Geography of Europe
    - IA311 Topics in German Culture I
    - IA337 European Romanticism
    - SV222 Western Civilization to 1500
    - SV223 Western Civilization from 1500 to the Present
    - SV291 Medieval Europe
    - SV413 Contemporary Germany
    - XX399 Special Topics
    - XX499 Directed Study
3. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
4. Substitutions may be made with the approval of the Minor Adviser.

MINOR IN GEOGRAPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Geography has the following requirements:

1. Five courses in Geography, one of which must be either World Regional Geography (GS291) or Cultural Geography (SV191).
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.
   Courses
    - GS191 Geography of Middle East
    - GS222 Modern Latin America

- IA238 African American Literature
- IA239 Rhetoric of Science
- IA240 Introduction to Shakespeare
- IA241 Introduction to Film Studies
- IA330 Documentary Film
- IA331 American Modernism
- IA333 Representations and Redefinitions of Reality
- IA334 Creative Writing
- IA335 Bible as Literature
- IA336 Mystery & Horror Literature
- IA337 European Romanticism
- IA338 Medicine in Literature
- IA339 Rebellion in American Literature
- IA341 Steinbeck and American Society
- IA342 Modern Southern Fiction
- IA431 History of the American Novel
- IA436 Reinterpretations of Literary Themes
- SV134 Popular Literature
- SV231 Introduction to Short Fiction
- SV232 Introduction to Non-Fiction
- SV233 Survey of American Literature
- SV332 Gender, Work & Popular Culture
-

First Year Courses
GE 111/112/113 German Language and Culture I/II/III JP 111/112/113 Japanese Language and Culture I/II/III
SP 111/112/113 Spanish Language and Culture I/II/III

Second Year Courses
GE 211/212/213 German Language and Culture IV/V/VI JP 211/212/213 Japanese Language and Culture IV/V/VI SP 211/212/213 Spanish Language and Culture IV/V/VI

Third Year Courses
GE 311 Topics in German Culture I/ GE312 Reading German Texts/313 Advanced Grammar and Translation Methods/ JP 311/312/313 Japanese Language and Culture VII/VIII/IX

Fourth Year Courses
GE 411 Technical Translation/412 Topics in German Culture II/413 Contemporary Germany/ JP 411/412/413 Japanese Language and Culture X/XI/XII

XX 399 Special Topics
XX 499 Directed Study

NOTES:
Credits earned in a first-year, first-term language do not count in satisfying HSS graduation requirements unless the second course in the sequence is also completed successfully.
Students who have completed high school courses in German, Japanese or Spanish can get credit-by-examination for their knowledge by completing subsequent advanced level courses.

MINOR IN MUSIC

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the Minor Advisor.

The Minor in Music has the following requirements:
1. Twenty credits (the equivalent of five courses) in Music. IA246, IA346, SV244, and four credits of IA348 are required.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Advisor.

Music Theory courses (both required):
- IA246 Music Theory I: Fundamentals of Tonal Music
- IA346 Music Theory II: Basic Form and Composition (pre-requisite: IA246)
Students who have taken music theory before attending Rose Hulman may choose to take a Theory I placement test in order to be granted admittance to Music Theory II. Students who successfully pursue this option must then substitute for Music Theory I another music related course, as approved by the Music Advisor.

Music History and Culture courses (one required; student may chose the other):
- GS243 Early European Music (Before 1650)
- SV244 Western Music of the Baroque, Classical, and Romantic Eras (required)
- SV245 Western Music in the 20th Century
- SV246 Popular Music in the Era of Recorded Sound
- GS343 Musics of the World

Music Performance (four credits required):
- IA348 Music Performance (pre requisite: consent of the ensemble director[s])
One credit represents one academic term of satisfactory participation in one accredited Performing Groups (Concert Band, Jazz Ensemble, String Ensemble/Orchestra, and Chorus). Maximum of two credits (that is, participation in two ensembles) per term. The four required credits need not be completed consecutively, nor must they all be completed in the same performing group. The specific criteria for “satisfactory participation” will be provided to the candidate by the ensemble directors.

MINOR IN PHILOSOPHY

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Philosophy has the following requirements:

1. Five courses in Philosophy, one of which must be Introduction to Philosophy (IA 101).

2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.

3. Substitutions may be made with the approval of the Minor Adviser.

Philosophy Courses:

- IA101 – Introduction to Philosophy
- IA102 – Critical Thinking & Introduction to Logic
- IA401 – Philosophy of Science
- IA302 – Philosophy of Religion
- IA301 – Philosophy of Mind
- IA303 – Political Philosophy
- SV402– Human Nature
- SV303 – Business & Engineering Ethics
- SV304 – Bioethics
- XX399 – Special Topics
- XX499 – Directed Study

Minor in Political Science

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Political Science has the following requirements:

1. Five courses in Political Science, one of which must be Comparative Politics (GS 161), International Relations (GS 163), or American Politics and Government (SV 166)
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the Minor Adviser.
   Courses
   - GS161 Comparative Politics
   - GS163 International Relations
   - GS361 Politics of the Global Economy
   - GS366 The European Union
   - SV166 American Politics and Government
   - SV369 British Politics and Government
   - IA463 Seminar on America's Future
   - XX399 Special Topics
   - XX499 Directed Study

Minor in Psychology

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

The Minor in Psychology has the following requirements:

1. Principles of Psychology (SV 171).

2. Four other psychology courses.

3. Engineering Statistics I (MA 223) or Introduction to Probability and Statistics with Applications (MA 381).

4. A minimum of 40 credits in HSS courses must be earned to obtain the minor.

5. Substitutions may be made with the approval of the Minor Advisor.

Courses:

- SV 171 Principles of Psychology
- SV 372 Social Psychology
- SV 472 Studying Human Behavior
- SV 373 Abnormal Psychology

IA 371 Cognitive Psychology
- IA 471 Computational Psychology
- IA 301 Philosophy of Mind

Minor in Theater and Drama

Students may apply only one (1) transfer course toward a minor. Exceptions may be made with the approval of the minor advisor.

Requirements:

1. Five courses (20 credits) in Theater and Drama.
2. A minimum of 40 credits in HSS courses must be earned to obtain the minor.
3. Substitutions may be made with the approval of the minor advisor.

Courses:

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Programs of Study

Army ROTC (Military)

The completion of the Army ROTC program leads to a commission as a Second Lieutenant in the Active Army, Army Reserve or Army National Guard. Students completing the program receive their commissions upon graduation and serve a specified period of active duty ranging from three months to four years, depending upon the student's choice of commissioning program and Army requirements.

CURRICULUM
The ROTC program specializes in teaching leadership and management skills required by the military and sought by civilian employers. ROTC cadets learn how to motivate co-workers and how to plan, organize and implement large projects and tasks. They also learn skills in demand in civilian businesses, such as teamwork, tact problem solving, decision making, and effective communication. The program includes the Basic Course for freshmen and sophomores and the Advanced Course for juniors and seniors. Students incur active duty and reserve commitments only upon enrollment in the Advanced Course or through the ROTC scholarship program and successful completion of the curriculum.

Students who miss out on the basic ROTC Freshman and Sophomore curriculum can attend a four-week (LTC) leadership training course at Fort Knox, KY., during the summer between their sophomore and junior years.

In the Advanced Course, students must complete 18 credit hours of Military Science and the 5-week ROTC Leadership Development and Assessment Course (MS 304) at Fort Lewis, WA. Qualified students may also participate in Army Airborne, Air Assault, Northern Warfare, or Mountain Warfare training.

Veterans and students who received ROTC training in high school should contact the Department concerning possible constructive credit for part or all of the Basic Course. Graduate students, transfer students and students who expect to complete degree requirements in less than four years should contact the Department concerning an accelerated program if they desire to obtain a commission. Other programs are available for selected students to complete the program in 2 years or less.

Allowances
Uniforms are furnished, when appropriate, to all students without charge. Students on scholarship and/or enrolled in the Advanced Course receive a monthly subsistence allowance that ranges from $250-400 per month during the school year and approximately $20 per day during the ROTC Advanced Camp, plus free room and board (meals).

Scholarships
ROTC awards Full-Tuition scholarships plus free Room/Board per year, providing money for tuition and educational fees. Scholarships are awarded strictly on merit, although the Institute provides an additional financial incentive. Scholarship winners also receive a designated textbook allowance of $900 per year and a tax-free stipend allowance from $300-500 per month for up to 10 months for each year the scholarship is in effect. Four-year scholarships are open to high school graduates prior to entering Army ROTC as freshmen. The three and two year scholarships are available to students enrolled in ROTC at Rose-Hulman. Full details on the scholarship program may be obtained by contacting the ROTC office at 1 (800)-248-7448, extension 8348 or 8236, or by visiting the Army ROTC home page at http://www.rose-hulman.edu/AROTC/

Partnership Institutions
Through a cooperative agreement, students at Indiana State University, Saint Mary-of-the-Woods College,

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

Additional Programs of Study

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

Freshman Year

		Credit
MS 101	Leadership and Personal Development	1
MS 102	Introduction to Tactical Leadership	1
MS 103	Basic Tactical Leadership	1
		3

Sophomore Year

		Credit
MS 201	Innovative Team Leadership	2
MS 202	Foundations of Tactical Leadership	2
MS		

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 d ofented withulman graduat8a9(8ineresearry, and bmcinogy.rgacially helps in cable,ry.rgacially helps havented wit -1.538edown specific minteresanufross purps w pMCor toichool Ad,

Lt Col Gregory Lowe Bergman III, CAPT Jeffers

AS 101 Foundations of the United States Air Force I 1R-2L-1C F Prereq: None
This is a survey course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

AS 102 Foundations of the United States Air Force II 1R-2L-1C W Prereq: AS 101 or instructor permission
This course is a continuation of the fall quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 103 Foundations of the United States Air Force III 1R-2L-1C S Prereq: AS 102 or instructor permission
This course is a continuation of the winter quarter course designed to introduce students to the United States Air Force and Air Force Reserve Officer Training Corps.

AS 101L/AS 102L/AS103L Leadership Laboratory

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LTC Eric Walthall and MSG Zoleske

FRESHMAN YEAR Basic Course

MS 101: Introduction to the Army and Critical Thinking 1R-3L-1C F Prereq: None

MS 101 introduces Cadets to the personal challenges and competencies that are critical for effective leadership. Cadets learn how the personal development of life skills such as critical thinking, time management, goal setting, stress management, and comprehensive fitness relate to leadership, and the Army profession.

MS 102: Adaptive Leadership and Professional Competence 1R-3L-1C W Prereq: MS 101 or Instructor Permission

MS 102 introduces Cadets to the personal challenges and competencies that are critical for adaptive leadership. Cadets learn the basics of the communications process and the importance for leaders to develop the essential skills to effectively communicate in the Army. Students will examine the Army Profession and what it means to be a professional in the U.S. Army .

MS 103: Basic Tact 03: Basic Tact 1.75 52.665 re ET BT 7.692-2.538 Td (MS 103: Basic Tact 03: BasicorR (Adaptive LeahBasic28 the U.S. Armt48 ess relate728 Basr0eske

up to $1200 annually for books and earn a monthly stipend of over $450 per month for 10 months per year. The Cadet Initial Entry Training Course is a way to catch up on missed Military Science courses in order to qualify the student for progression as a contracted Advanced Course ROTC cadet.

JUNIOR YEAR Advanced Course

MS 301: Training Management and the Warfighting Functions 3R-3L-4C F Prereq: MS 206, or completion of Basic Course requirements, or prior military service (contact Military Science Department for specific requirements established in Army Regulations)
MS 301 Cadets will study, practice, and apply the fundamentals of Army Leadership, Officership, Army Values and Ethics, Personal Development, and small unit o7 rshM(þÿrv4928.30ionlDeve.F)Tj ET BT /Span <</ActualText (þÿ)>>BDC 7.6928 0 0 7.6928 230.3075 695.8012 Tm73.
MS 32 urses icreBasngplyintenscesictuctionall eadershi chmalengses tobulldC cade awarenres, and kwiles inl eatinc

and completed prior to graduation and commissioning. A complete listing of all applicable PME courses is available through the ROTC department.

Biology & Biomedical Engineering

Biology and Biomedical Engineering Faculty: Ahmed, Anthony, Buckley, Chiu, Coppinger, Dee, Hill, Ingram, Livesay, O'Connor, Rogge, Waite, and Weiner.

Biology

BIO 101 Essential Biology 4R-OL-4C F,W,S Prereq: None
Surveys basic concepts in the biological sciences and describes how new advances related to these concepts affect contemporary society. Students who have completed BIO110, BIO120 or BIO130 cannot receive credit for taking BIO101.

BIO 102 Nutrition 4R-0L-4C W Prereq: None
This course surveys essential concepts in the nutritional sciences, including food composition, diet construction and analysis, physiological processes, and special nutritional needs for certain groups. This course counts as a free elective for BIO or BE majors and not as an BIO elective.

BIO 110 Cell Structure and Function 3R-3L-4C F,S Prereq: None
Introduces structures, mechanisms, and laboratory techniques in cellular and molecular biology. Discusses biomolecules, bioenergetics, biosynthesis, enzymatic function, genetics, and cellular regulatory systems.

BIO 120 Comparative Anatomy & Physiology 3R-3L-4C W Prereq: None
The structural and functional relationships between tissues and organ systems are discussed using a comparative approach. The lecture is combined with laboratory exercises and observations, which may require dissection of biological specimens.

BIO 130 Evolution and Diversity 3R-3L-4C S Prereq: None
Introduces fundamental principles, important applications, and field and laboratory techniques in organismal biology. Discusses mechanisms of evolution, the history of life on earth, biological diversity, and ecology.

BIO 191 Special Topics in Biology XR-0L-XC Arranged Prereq: Consent of instructor
Covers material of mutual interest to students and instructors which cannot be acquired in any other listed BIO course.

BIO 205 Cellular Physiology 4R-0L-4C F Prereq: BIO 110
The flow of information in biological systems provides a framework for detailed discussion of cell structure and function, with particular attention paid to the physiology of excitable cells. Cellular communication and the interactions of cells in tissues and the immune system are also examined. Reproduction and organismal development will also be addressed at the cellular level. A student who earns credit for BIO205 cannot earn credit for BIO210 or BIO230 without departmental consent.

BIO 210 Mendelian and Molecular Genetics 3R-3L-4C F Prereq: BIO 110 or instructor consent
A discussion of Mendelian genetics including the molecular mechanisms of nuclear and cytoplasmic inheritance. Information flow and control of gene expression are addressed at the molecular level. Basic genetic techniques are covered in both lecture and laboratory.

BIO 220 Microbiology 3R-3L-4C W Prereq: BIO 110 or instructor consent
Discusses the essential properties of eubacteria and archea. Bacterial nutrition, growth, genetics and structural

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Civil Engineering
College & Life Skills
Computer Science & Software Engineering
Electrical & Computer Engineering
Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

This course focuses on cancer at the molecular and cellular level. Specific cellular molecules and the changes to these cellular molecules that contribute to transformational and immortalization of cells and tumor progression will be studied. The mechanisms behind these molecular changes, cancer promotion and initiation events, and cancer molecule-specific treatment options will be addressed. In addition, students will study a variety of specific cancer types.

BIO 461 Evolutionary Medicine 4R-0L-4C Arranged Prereq: BIO 130, and BIO 205 or BIO 210, or instructor consent.
This course examines medicine and medical practice from the perspective of evolutionary constraints, challenges, and diversity. Topics include theoretical foundations of the field, cancer patterns, mental health, genetic disease, evolutionary health promotion, and others.

BIO 471 Genetic and Molecular Analysis of Inherited Human Disease 4R-0L-4C S Arranged
Prereq: BIO 205 or BIO 210 or consent of instructor

BE 510 Biomedical Signal and Image Processing 3R-3L-4C W Prereq: BE201, JR, SR or Graduate standing or consent of instructor
Provides a comprehensive survey of signal and image processing tools for biomedical applications. Major biological signals (e.g., ECG), biomedical imaging techniques (e.g., MRI), their origin and importance, and the commonly used processing techniques with an emphasis on physiology and diagnostic applications will be discussed.

BE 511 Analysis of Physiological Systems I 3R-3L-4C W Prereq: Junior, Senior, Graduate standing or consent of instructor
An analysis of neural, muscular, endocrine, and digestive physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. Students enrolled in BE511 must complete a project not covered in BE310. Students may not receive credit for both BE511 and BE310.

BE 512 Analysis of Physiological Systems II 3R-3L-4C S Prereq: Graduate standing or consent of instructor
An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach. Both recent and classical journal articles will be discussed in class. (Note: BE511 is not a prerequisite for BE512). Students enrolled in BE512 must complete a project not covered in BE320. Students may not receive credit for both BE512 and BE320.

BE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing
Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, EP 510, and ME 516.

BE 520 Introduction to Brain Machine Interfaces 3R-3L-4C S Prereq: BE340 or ECE480
This course is an introduction to the basics of motor cortical functions related to voluntary and imagery movements, evoked response potentials, invasive vs. noninvasive electrode design considerations, quantitative EEG analysis techniques used in clinical settings, and the applications of brain-machine interfaces/gs, an 3canons g-3kaylnalysnd tl oal 7.6sthitf/ cromachining, thin-film dep

BE 541 Medical Imaging Systems 4R-0L-4C Prereq: Graduate standing and BE340, or BE340 with a grade of B or better, or consent of instructor.
Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as ECE584.

BE 543 Neuroprosthetics 3R-3L-4C Prereq: BE310 and BE201
This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 Orthopaedic Biomechanics 4R-0L-4C Prereq: EM 203 or EM 204, and BE 331 or consent of instructor
This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 Research Methods in Biomechanics 3R-3L-4C W Prereq: BE 331 or consent of instructor
Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 555 Electrophysiology 3R-3L-4C Prereq: Junior, Senior, Graduate standing or consent of instructor
Introduces students to concepts of electrical activity in cells and organs of the body. Topics include: origin of membrane potential, membrane channels, synaptic signaling, recording techniques, gross electrical potentials (e.g. electrocardiogram, electroencephalogram, electromyogram, electroretinogram). Emphasis will be placed on how these signals are used to probe physiological function in the clinic and in the research laboratory.

BE 560: Tissue-Biomaterial Interactionhods used in the field of biomechanics. Currenp0a0.72havme9.60103 757.935 Tm 17.783 -40.912 Td ( )Tj EMC ET BT 7.6928 0 097.6

BIOMATHEMATICS CORE

BMTH 310 Mathematical Biology 4R-0L-4C F Prereq: MA 211, MA 212.
This course emphasizes the application of differential equations and probability theory to modeling and analyzing dynamic biological systems. Mathematical topics include ordinary and partial differential equations, discrete dynamical systems, bifurcations, limit cycles, chaos, and probabilistic and stochastic modeling. Biological applications may include, but are not limited to, biochemistry, molecular and cellular biology, epidemiology, neurophysiology, ecology, sociology, and pattern formation.

BMTH 311 Systems Biology 4R-0L-4CWPrereq: MA 211, MA 212. MA 212 may be taken concurrently with instructor permission.
The study of how to combine detailed biological information to build models of entire systems. Nearly any biological scale can be considered. For example, at the biochemistry level the course will consider topics such as gene regulatory networks, protein interaction networks, and metabolisms. Moving toward larger scales, systems biology can be used to study the growth of cancerous tumors, and on an even larger scale, the mating and social structure of populations. The course's focus is on how to use relational information to perform model based inquiries of an entire system.

BMTH 312 Bioinformatics 4R-0L-4C S (odd years) Prereq: CSSE 120 and MA 381.
This course will study how to combine mathematical, statistical, probabilistic, and computational methods to analyze biological data. Example topics are sequence alignment, locating genes, structural alignment, microarray analysis, and drug design. The course emphasizes how to search and compare biological datasets to make scientific inferences.

BMTH 413 Computational Biology 4R-0L-4C S (even years) Prereq: MA 332 and one of BMTH 310/311/312.
The study of how to build and validate computational models to conduct biological studies. Ex-emplary topics include molecular dynamics, haplotyping, phylogenetics, neuroscience, and population dynamics. The course will consider the implementation and analysis of algorithms that are specifically germane to the life sciences.

BMTH 310	Mathematical Biology
BMTH 413	Computational Biology

Physiology

BIO 120	Comparative Anatomy and Physiology
BIO 205	Cellular Physiology
BE 310/320	Analysis of Physiological Systems I & II
BE 520	Introduction to Brain Machine Interfaces

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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 Prereq: CHEM 115 or consent of instructor
Introduction to the properties and processing of metals, ceramics, polymers, and semiconductors. The influences of crystal structure, interatomic bonding, and electronic structure on physical, mechanical, and electrical properties are emphasized. Causes and mitigation of various types of corrosion are explored. Properties and design of composite materials are introduced.

CHE 320 Fundamentals of Heat and Mass Transfer 4R-0L-4C F,W Prereq: CHE 202, CHE 301, MA 211, MA 212, Co: CHE 304
Discussion of fundamental heat and mass transfer principles: conduction, forced and free convection, radiation, and diffusion. Mathematical analysis and computation of heat transfer, mass transfer, temperature, and concentration profiles in systems with simple geometries. Finite difference equations. Estimation of local and overall heat and mass transfer coefficients.

CHE 321 Applications of Heat and Mass Transfer 4R-0L-4C W,S Prereq: CHE 320, CHE 304
Use, design, and selection of heat exchangers and heat exchange systems for various applications in the chemical process industries. Study of gas-liquid and liquid-liquid mass transfer operations including gas absorption, extraction, and distillation in equilibrium staged tray columns and packed columns. Quantitative treatment of mass transfer based on material and energy balances, phase equilibrium, and rates of heat and mass transfer. Applications of radiation heat transfer, boiling, and condensation.

CHE 404 Kinetics and Reactor Design 4R-0L-4C F,S Prereq: CHEM 360 and CHE 304
The course covers homogeneous kinetics, differential and integral data analysis, batch, mixed, and plug flow reactors, systems with multiple reactions, reactor cascades, and temperature and energy effects.

CHE 405 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR Standing (See EP 410/510.)
Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with ECE 416, EP 410, and ME 416.

CHE 409 Professional Practice 1R-0L-1C F Prereq: Senior Standing in Chemical Engineering
Topics on professional practice, ethics, and contemporary and global issues in the profession are discussed.

CHE 411 Chemical Engineering Laboratory I 2R-3L-3C S Pre: CHEM 115, CHEM 225, CHEM 252, CHE 320, MA223, RH330
Principles underlying momentum, mass and energy transfer and the applications of equipment used to accomplish such transfer, introduction to laboratory concepts in data collection, record keeping, interpretation and analysis, and instrumentation including experimental error analysis, regression, model formulation, experimental design, and instrumentation. Written and oral reports are required. Formal instruction on written and oral communication and teaming will be provided.

CHE 412 Chemical Engineering Laboratory II 2R- 6L-4C F Prereq: CHE 321, CHE 411 or consent of instructor
Continuation of principles underlying momentum, mass and energy transfer with some emphasis on kinetics, applications of equipment used to accomplish such transfer.

CHE 413 Chemical Engineering Laboratory III 2R- 6L-4C W Prereq: CHE 412
Continuation of CHE 412 with emphasis on process control and kinetics.

CHE 416 Chemical Engineering Design I 4R-0L-4C F Prereq: CHE 321
Introduction to the design process; simulation to assist in process creation; synthesis of separation trains; design of separation equipment; and capital cost estimation.

CHE 417 Chemical Engineering Design II 4R-0L-4C W Prereq: CHE 416, CHE 404
Design of reactor-separator-recycle networks; heat and power integration; batch process scheduling; annual costs, earnings and profitability; preliminary work on a capstone design project.

CHE 418 Chemical Engineering Design III: Capstone Design Project 0R-6L-2C S Prereq: CHE 417 or consent of instructor
Completion of an open-ended design project that will include written and oral communication of intermediate

results and a final written report.

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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CHEM 113 General Chemistry II

CHEM 111 General Chemistry I 3R-3L-3C F,W,S Prereq: None; Coreq: CHEM111L

Topics include stoichiometry, nomenclature, phases, and writing balanced chemical equations. Quantum theory is introduced in relation to chemical applications. Atomic structure is introduced. Bonding principles and molecular structure are discussed in terms of Lewis Dot Structures, Valence Bond Theory, VSEPR Theory, Hybridization, and Molecular Orbital Theory.

CHEM 111L General Chemistry I Laboratory 0R-3L-1C F,W,S Prereq: None; Coreq: CHEM 111

Fundamental chemistry laboratory skills are introduced along with data analysis in support of topics presented in CHEM111 recitation.

CHEM 112 Chemistry Honors 4R-3L-5C **F** Prereq: Advanced placement

An accelerated course covering topics in CHEM 111 and CHEM 113. Upon successful completion of this course, an additional 3 credits will be awarded. Enrollment is limited to those students who complete the Rose-Hulman online Chemistry Advanced Placement Examination given prior to the freshman orientation period.

CHEM 113 General Chemistry II 3R-3L-3C **W,S Prereq: CHEM 111 and** CHEM 111L; Coreq: CHEM 113L

Topics in this course include the fundamentals of thermodynamics and kinetics. The fundamentals of chemical equilibrium are introduced. Definitions of acid and bases are discussed utilizing the Bronsted-Lowry and Lewis models. Nuclear chemistry is also included.

CHEM 113L General Chemistry II Laboratory **0R-3L-1C** W,S

CHEM 433 Biochemistry Laboratory 0R-3L-lC S Prereq: CHEM 330
Fundamental techniques employed in isolation, characterization and study of biomolecules, and enzyme kinetics. Techniques used may include homogenization, solvent extraction, centrifugation, salt fractionation, chromatography, and electrophoresis.

CHEM 441 Inorganic Chemistry I

CHEM 531 Biochemical Instrumentation 3R-4L-4C Prereq: BIO 210 and CHEM 330
This project-based course includes approaches for the analysis of biochemical experimental problems, experimental design for molecular biology and biochemistry, and the theoretical basis and practical aspects of operating instruments used in biochemical research.

CHEM 532 Biochemical Pharmacology 4R-0L-4C Prereq: CHEM 330
Topics include medicinal chemistry and molecular pharmacology. The topics will also include a survey of potential drug targets, the molecular interactions between drugs and their targets, the drug discovery and development process and case studies of drugs treating diseases such as cancer, bacterial and viral infection, and neurological disorders.

CHEM 545 Organometallic Chemistry 4R-0L-4C Prereq: CHEM 115, CHEM 252
A survey of the chemistry of main group organometallic compounds and organo-transition metal complexes. Reaction mechanisms and uses in organic synthesis and catalysis are studied.

CHEM 552 Synthetic Organic Chemistry 4R-0L-4C Prereq: CHEM 253
A survey of contemporary methodology in organic synthesis. Retrosynthetic analysis, functional group transformations, condensation chemistry, and organometallic reagents will be stressed. Includes computer assisted synthesis.

CHEM 554 Theoretical Organic Chemistry 4R-0L-4C Prereq: CHEM 253 and CHEM 361 or CHEM 360 or permission of instructor
Study of physical and chemical methods used to investigate organic reaction mechanisms; the chemistry of carbenes; organic photochemistry.

CHEM 555 Natural Products 4R-0L-4C Prereq: CHEM 253 or permission of instructor
A study of naturally occurring materials such as carbohydrates, lipids, amino acids, terpenes and steroids. The course also entails a discussion of synthesis, biosynthesis, structure elucidation, selected degradation and other reactions as well as some medicinal characteristics of selected natural products.

CHEM 557 Synthetic Polymer Chemistry 4R-0L-4C Prereq: CHEM 252
Polymer synthesis, reactions, and applications. Organic chemistry of polymer synthesis and modification. Design of polymer systems that meet certain performance criteria or have desirable physical properties.

CHEM 561 Advanced Physical Chemistry 4R-0L-4C Prereq: CHEM 363
Addresses a variety of topics in quantum mechanics, statistical thermodynamics or kinetics.

CHEM 562 Physical Polymer Chemistry 4R-0L-4C Prereq: CHEM 361 or CHE 303
Physical behavior of polymers. Physical properties, molecular weight determination, relationship between morphology and mechanic CHEM 252

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Civil Engineering

Professors Aidoo, Chapman, Hanson, Kershaw, Lovell, Marincel Payne, McKinney, Mueller Price, Robinson, and Sutterer.

CE 101 Engineering Surveying 0R-6L2C F Prereq: None
Covers basic principles and practices of surveying. Measurement through the application of surveying techniques; theory of errors and their analysis; concepts of horizontal, vertical, and angular measurement; coordinate systems; basic surveying operations and computations; reading and interpretation of building, highway, and/or bridge plans; traverse computations; applications to construction and design.

CE 111 Geographical Information Systems 2R-0L-2C W Prereq: None
The course covers introductory concepts of geographical information systems and related technologies. Topics covered will relate to the use, collection, creation, and analysis of spatial data in applying GIS and related technologies to civil engineering projects.

CE 205 Thermodynamics 4R-0L-4C F Prereq: MA 112
Covers first law of thermodynamics, second law of thermodynamics, concept of entropy, simple process analysis, properties of pure substances, equations of state, and state diagrams. Stresses use of property tables and charts and application of the first and the second laws to open and closed systems undergoing changes.

CE 250 Sustainable Civil Engineering Design 2R-0L-2C W Prereq: EM 103
An introduction to sustainable design of civil engineering systems. Includes treatment of current issues as they relate to design and construction for economic, environmental and social aspects of civil engineering.

CE 303 Engineering Economy 4R-0L-4C W Prereq: None
Emphasizes time value of money and factors related thereto. Familiarizes students with concepts of annual cost, present worth, and minimum rate of return as tools for consideration of economic factors pertinent to the selection of alternate solutions to engineering problems.

CE 310 Computer Applications in Civil Engineering 2R-0L-2C S Prereq: CE371 and CE432
Students develop solutions to a variety of civil engineering problems using application programs such as Mathcad, Excel, and Matlab. Emphasis is made on problem solving approach and structured programming with software tools useful to civil engineering computation and design.

CE 320 Civil Engineering Materials 3R-3L-4C S
A study of the origin, nature, performance and selection criteria of various basic materials used in the practice of civil engineering. These include aggregates, portland cement, concrete, and bituminous materials. Emphasis will be placed on standard methods of testing and characterization as related to the mechanical behavior of materials.

CE 321 Structural Mechanics I 4R-0L-4C F Prereq: EM 203
Classical structural analysis. Idealizations, stability, reactions and internal forces, influence lines, approximate analysis, and displacements.

CE 336 Soil Mechanics 3R-3L-4C F Prereq: EM 203 and EM 301
Introduces the student to the fundamental concepts of soil mechanics. Covers types and properties of soils, lateral and vertical pressures, settlement and consolidation, strength and seepage studies. Includes laboratory

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Engineering Management
Engineering Mechanics
Engineering Physics
Engineering Science
Geology
Humanities and Social Sciences
Mathematics
Mechanical Engineering
Multi-Disciplinary Studies
Optical Engineering
Physics

investigation of soil properties.

CE 371 Hydraulic Engineering 3R-3L-4C F Prereq: EM 301 or equivalent
Application of basic fluid mechanics principles to the fields of hydraulics and water resources. Topics covered include: open channel flow, closed conduit flow, flow measurement, and turbomachinery. Stresses practical applications in the laboratory.

CE380 Introduction to Transportation Engineering 4R-0L-4C S Coreq: MA223, CE320
Study of transportation functions and transportation systems; measuring and estimating demand; characteristics of transportation modes, interactions between modes, and mode interfaces; social, environmental, technological, economic, and public policy impacts; techniques of transportation system planning, design, and operation, with an emphasis on highway geometric design.

CE 400 Career Preparation Seminar 1R-0L-0C S Prereq: CE 488
Preparation for the student to become a practicing engineer. Topics include Civil Engineering job expectations, continuing education, legal considerations, professionalism, consumer topics, and financial considerations.

CE 420 Consulting Engineering Seminar 2R-0L-2C S Prereq: Junior class standing
Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with BE 400, CHE 420, ECE 466, and ME 420.

CE 421 Structural Mechanics II 4R-0L-4C W Prereq: CE 321
Hand methods for structural analysis of indeterminate structures: approximating drift of frames and solid walls, force method, moment distribution method, distribution of shear when there is a rigid diaphragm, and in-plane diaphragm forces.

CE 431 Structural Design in Steel I 3R-0L-3C S Prereq: CE 321
Covers the analysis and design of the basic elements of a steel structure using Load and Resistance Factor

quality modeling.

CE 461 Environmental Engineering laboratory 1R-3L-2C S Coreq: CE 460

course instructor
Provides the opportunity for the civil engineering students to do a selected project of mutual interest to them and a faculty member or make up for deficiencies in transfer credit hours and topics. Credit is assigned up to 4 credits per term with a maximum of 8 credits toward graduation.

CE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

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CE 536 Advanced Soil Mechanics 4R-0L-4C On Demand Prereq: CE 436
Presents a comprehensive treatment of principles of soil mechanics in relation to soil compaction, effective stress, influence of fluid flow on soil behavior, pore pressure development in undrained loading, consolidation, settlement problems, lateral soil pressures, shear strength and stability problems.

CE 537 Retaining Structure Design 4R-0L-4C W Prereq: CE 336, CE 432
Covers the determination of earth pressures, selection of appropriate retaining wall types, and design of commonly used retaining structures. Includes both external (geotechnical) and internal (structural) analysis.

CE 561 Air Pollution 4R-0L-4C W Prereq: Grad or consent of Instructor
Fundamentals of meteorology, air pollution health impacts, particulate control mechanisms and devices, and gaseous pollutant control mechanisms and devices. Course includes detailed design projects involving major air pollution control devices. Cross-listed with CHE450.

CE 562 Advanced Wastewater Treatment 4R-0L-4C Prereq: CE 463
Covers the theory, design and analysis of biological processes for the treatment of wastewater. Treatment processes include suspended and attached growth processes, aerobic and anaerobic processes, biological nutrient removal, aeration and gas transfer, and biosolids processing.

CE563 Advanced Water Treatment 4R-0L-4C Prereq: CE 463
Covers the theory, design and analysis of physical and chemical processes for the treatment of drinking water. Treatment processes include coagulation and flocculation, gravity separation, granular and membrane filtration, disinfection, air stripping, adsorption, ion exchange, and disinfection.

CE 564 Aquatic Environmental Chemistry 4R-0L-4C F Prereq: Senior or Graduate student standing
Emphasis equilibrium relationships of importance in understanding both natural waters and wastewaters. The carbonate system and the concept of pH as a master variable are stressed.

CE 565 Solid & Hazardous Waste Regulation & Treatment 4R-0L-4C On Demand Prereq: CE 460
Covers solid and hazardous waste management, including characterization, collection system design, waste minimization, design of landfills and incinerators, and remediation principles.

CE 566 Environmental Management 4R-0L-4C On Demand Prereq: Graduate student standing
Environmental management at an industrial facility is examined in detail. Topics include the determination of environmental impacts, summaries of main environmental laws and standards, decision-making tools, and case studies of various industries.

CE 567 Applied Hydrologic Modeling 4R-0L-4C Prereq: CE 471
Watershed planning and stormwater management strategies are examined using computer simulation models. With an emphasis on conceptual foundation, students will be introduced to some of the most widely used models in the fields of hydrology and stormwater quantity management. Topics examined include watershed loss, transform, and routing methods, as well as model configuration, calibration, and evaluation.

CE 568 Surface Water Quality Modeling 4R-0L-4C S Prereq: CE 460 or consent of instructor
Covers the mathematical analysis of transport and fate of pollutants in natural surface waters and their impact on water quality using analytical and numerical models. Includes one- and two-dimensional steady-state and transient models. Pollutants examined include oxygen-demanding organics, nutrients and toxic compounds.

CE 569 Treatability Studies 2R-6L-4C On Demand Prereq: CE 563 or CHE 461
Emphasizes use of laboratory bench scale evaluations of unit operations and processes important in the treatment and disposal of specific types of organic and inorganic wastes of significance in industrial and site remediation situations. Student laboratory projects and presentations.

CE 570 Modeling Open Channel Hydraulics 4R-0L-4C W Prereq: CE 371
Presents steady and unsteady flow problems in open channels and pipes, dealing with mechanics of flow over rigid and mobile boundaries. Covers analysis of river dynamics and hydraulic principles in stormwater conveyance through numerical and computer modeling.

CE 571 Environmental River Mechanics 3R-3L-4C S Prereq: CE 371
Concepts of fluvial geomorphology and fluvial hydraulics are examined, including natural stream flow, sediment transport, and ecological processes in alluvial rivers. Students will apply these principles to solve common design problems of channel instability and rehabilitation of impaired streams. Students will visit local streams to perform field data collection of channel geometry, bed and bank material, and water quality.

CE 573 Groundwater Analysis 4R-0L-4C Prereq: CE 471
Covers hydrodynamics of flow through porous media. The primary emphasis is on the analysis of steady and

unsteady flow in confined and unconfined aquifers. Groundwater modeling is introduced.

CE 589 Environmental Engineering Design and Synthesis 4R-12L-8C Prereq: Graduate Standing
F,W,S,F
Environmental engineering projects submitted by external sponsors are undertaken by small teams of students to develop advanced principles used in planning, design, and synthesis. Final recommendations and engineering designs are presented to the sponsors with due attention to the social, economic, and ethical constraints of the project. Each student team also prepares a manuscript of the completed project that is suitable for publication 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.

CLSK 100 College and Life Skills 1R-0L-1C F Prereq: None
This course will assist Rose-Hulman students in acquiring life skills and in learning more about themselves. These new skills will assist the student in a smooth transition from high school to college and will provide the students with the tools necessary for success as a student and in life. Additionally this course will introduce students to people and resources at Rose-Hulman who can assist them in providing a positive educational as well as personal experience.

CLSK 121 College English 4R-OL-4C Prereq: Consent of Instructor
Focuses on understanding the basic patterns and conventions of writing, enhancing reading skills and written comprehension, and improving verbal communication and oral comprehension. This course is intended for students for whom English is a second language. Students required to take CLSK121 must successfully complete the course prior to taking RH131.

CLSK 122 English Language and Culture in Academic Texts 3R-3L-4C Prereq: Consent of instructor required
Reviews English grammar and introduces and develops deeper understanding of academic vocabulary. Familiarizes students with essential essay structures in academia. Introduces academic readings in select topics of academic concern in American socio-culture. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 123 English Language in Academic Research and Composition 3R-3L-4C Prereq: Consent of instructor required
Introduces students to formal research and composition of research papers. Strengthen students' formal research and writing skills for research papers. Guides students through readings in academic journals and articles. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 124 English Language and Culture in Academic Speech, Presentation, and Argumentation 3R-3L-4C Prereq: Consent of instructor required
Emphasizes fluency in spoken English. Rehearses academic vocabulary. Prepares students for academic presentations including technology. Develops students' academic listening and note-taking skills focusing on topics of American socio-cultural study. Introduces students to Socratic discussion and argumentation. The course does not satisfy any Rose-Hulman degree requirement.

CLSK 125 English Rhetoric and Culture in Academia 3R-3L-4C Prereq: Consent of instructor required
Prepares students for full-length lectures in courses related to their majors, focusing on oral rhetoric devices. The course does not satisfy any Rose-Hulman degree requirement.

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Chemistry and Biochemistry
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Engineering Physics
Engineering Science
Geology
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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

CSSE 489 Senior Research Project III 4C Arranged Prereq: CSSE488
Individual or group research on an unsolved technical problem. The problem is expected to be at an advanced level and have an appropriate client. A prototype system, a technical report, and a public presentation are required.

CSSE 490 Special Topics in Computer Science 1-4C Arranged Prereq: Permission of instructor
Selected topics of current interest. May be repeated for credit if topic is different.

CSSE 491 Directed Independent Studies 1-4C Arranged Prereq: Permission of instructor and department head
Independent study of an advanced subject not included in regularly offered courses. May be repeated for credit if topic or level is different.

CSSE 492 Undergraduate Research in Computer Science 1-4C Arranged Prereq: Permission of instructor and department head
CSSE 493 Undergraduate Research in Software Engineering 1-4C Arranged Prereq: Permission of instructor and department head
Research under direction of a faculty member. Presentation of preliminary and final results to departmental seminar. Presentation of work at professional meetings or by publication in professional journals is strongly encouraged. May be repeated for credit if topic or level is different.

CSSE 494 Senior Thesis I 4C Arranged Prerequisite: RH330 and Permission of instructor and department head
CSSE 495 Senior Thesis II 4C Arranged Prerequisite: CSSE494
CSSE 496 Senior Thesis III 4C Arranged Prerequisite: CSSE495
Individual study and research of a topic in computer science or software engineering. Topic is expected to be at an advanced level. Research paper and presentation to department seminar are required.

CSSE 497 Senior Capstone Project I 4C F

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Professors Berry, Chang, Doering, Grigg, Herniter, Hudson, Kim, Miller, Moore, Mu, Padgett, Rostamkolai, Simoni, Song, Throne, Walter, Wheeler, and Yoder.

ECE 160 Engineering Practice 0R-4L-2C F,W Prereq: none
The principles of system engineering design and teamwork are used by student teams as they design, test, and build an autonomous robot to meet a set of performance specifications. An end-of-term competition for testing the robots' performance to meet the design specifications and for honor and glory features exciting matchups between teams. Students and instructors are encouraged to have fun throughout the course!

ECE180 Introduction to Signal Processing 3R-3L-4C F, W, S Pre: MA112 and either CSSE120 or prior programming experience
An introduction to discrete-time signal processing applied to audio, images, and video. Topics include phasor representation of sinusoidal signals, complex arithmetic, sampling, signal spectra, linear time-invariant systems, frequency response, convolution, filter implementation, and MATLAB programming. Integral laboratory.

ECE 203 DC Circuits 3R-3L-4C S,F Prereq: MA111 and PH112
Definition of voltage, current, energy and power. Ohm's Law. Non-ideal dc voltage and current sources. Measurement of voltage, current and resistance. Kirchhoff's Laws. Circuit simplification by series and parallel reduction. Thevenin, Norton and Maximum Power Theorems. Superposition Theorem. Mesh and Nodal Analysis. Two-Port Circuits. Operational Amplifiers. Integral laboratory.

ECE 204 AC Circuits 3R-3L-4C F,W Prereq: PH113 and either ECE203 with a grade of C or better or ES203 with a grade of C or better
Capacitance, Self and Mutual Inductance. Root-mean-square values of waveforms. Application of phasors to sinusoidal steady-state. Impedance of circuit elements. Mesh and Nodal Analysis applied to ac circuits. Thevenin and Norton theorems applied to ac circuits. Single-phase ac power. Power factor correction. Voltage regulation and efficiency of feeders. Balanced three-phase systems. Ideal and non-ideal transformer models. Integral laboratory.

ECE 205 Circuits and Systems 3R-3L-4C W, S Prereq: MA211, ECE180, RH131 and either ECE203 with a grade of C or better or ES203 with a grade of C or better
Introduction to 1st and 2nd order circuits and review of differential equations. Bode plots. System classification, impulse and step response, convolution. Laplace and inverse Laplace transforms, block and signal flow diagrams. Benefits of feedback. Modeling and simulating electrical systems. Matlab and Simulink. Integral laboratory.

ECE 206 Elements of Electrical Engineering 4R-0L-4C W,S Prereq: MA 211

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 An1 Tf cbn techniques. Electric and

Design process, modeling; analytical and numerical. Actuators; dynamics and thermal issues. Use of software for layout and simulation. Characterization and reliability of MEMS devices. Electrical interfacing and packaging of MEMS. Microsensors, microfluidic systems, applications in engineering, biology, chemistry, and physics. Cross-listed with EP 411, and CHE 419.

ECE 420 Discrete-Time Control Systems 4R-0L-4C F Prereq: ECE 320 or ME 406
Sampled systems and z-transforms. Transfer function and state-variable models of systems. Discrete-time control of systems including state variable feedback and observer construction.

ECE425 Introduction to Mobile Robotics 3R-3L-4C W Prereq: CSSE 120 and (ECE 320 or ME 406 or BE 350 or CHE 440)
This course will introduce the basic principles of mobile robotics history, theory, hardware and control. Topics will include robot components, effectors and actuators, locomotion, sensors, feedback control, control architectures, representation, localization and navigation. This is a project-oriented course and the student will have hands-on experience with a real mobile robot. The student will be required to complete several laboratory assignments and a multidisciplinary team design project.

ECE 430 Microcontroller-Based Systems 3R-3L-4C F Prereq: ECE 250 for ECE students, consent of instructor for other students.
Microcontroller register set, addressing modes and instruction set. Microcontroller peripheral support modules. Assembly language and C programming. Fundamental data structures. Interrupts. Real time programming. Data communications. Microcontroller interface to displays, digital and analog devices, sensors, and actuators. Embedded system design, implementation and applications. Integrated development environment. Formal final report and oral presentation. Integral laboratory. Credit cannot be obtained for both ECE 331 and ECE 430.

ECE 452 Power Electronics 3R-3L-4C F Prereq: ECE 250
Analysis and design of networks that use electronic devices as power switches. Silicon-controlled rectifiers, power transistors, and power MOSFETS are used to form phase-controlled rectifiers, AC voltage controllers, choppers, and inverters. Integral laboratory.

ECE 454 System Level Analog Electronics 3R-3L-4C W Prereq: ECE 351
Analysis and design of Op-Amp circuits: wave shaping circuits, Schmitt triggers, power amplifiers, high power buffers, controlled current sources, peak detectors, sample and hold circuits. Precision Op-Amp Circuits. Non-ideal properties of Op-Amps. Integral laboratory.

ECE 460 Engineering Design I 1R-6L-3C F, W Prereq: ECE362
For EE: Prereq or concurrent registration in the remainder of ECE230, ECE310, ECE320, ECE341, ECE351, ECE370 or ECE371, ECE380
For CPE: Prereq or concurrent registration in the remainder of CSSE332 or CSSE230, ECE250, ECE230, ECE312, ECE332, ECE343, ECE380 or ECE320
A continuation of a sequence of formal design courses that emphasizes completion of a client-driven project using a formal design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

ECE 461 Engineering Design II 1R-9L-4C W, S Prereq: ECE460
Continuation of the design project from ECE460. Integral laboratory.

ECE 462 Engineering Design III 1R-3L-2C W,S Prereq: ECE461
Completion of the design project from ECE 460 and ECE 461. Integral laboratory.

ECE 466 Consulting Engineering Seminar 2R-0L-2C Prereq: Junior class standing
Discussion problems in the field of consulting engineering; seminars presented by practicing consulting engineers. Cross-listed with BE 400, ME 420, CHE 420, and CE 420.

ECE 470 Power Systems I 3R-3L-4C F Prereq: ECE 370
Per-unit concepts. Modeling and analysis of synchronous machines. Configuration of transmission and distribution lines. Modeling of power system components. Formulation of power flow equations. Computer solutions of the load-flow problem. Fault-level evaluation by symmetrical components. Principles of grounding. Integral laboratory.

ECE 471 Industrial Power Systems 4R-0L-4C W Prereq: ECE 370
Design and analysis techniques for low and medium voltage power distribution systems. Harmonics, transients, system coordination, reliability and economics. A design project is carried throughout the course.

ECE 472 Power Systems II 3R-3L-4C S Prereq: ECE 470

Power system protection and stability. Design and application of relaying schemes for protection of transformers, buses, distribution lines, transmission lines, generators, motors, capacitors, and reactors. Power system stability and generator rotor dynamics phenomenon with use of the equal-area criterion. Integral laboratory.

ECE 473 Control of Power Systems 3R-3L-4C W Prereq: Senior standing or consent of instructor
Principles of interconnected operation of power systems. Optimum scheduling of generation using economic dispatch and unit commitment. Primary and secondary load-frequency control. Voltage and reactive-power flow control. Principles of state estimation. Integral laboratory.

ECE 480/OE 437 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212
Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments.

ECE 481 Electronic Music Synthesis 4R-0L-4C S Prereq: ECE 380
Analog synthesis techniques. Instrument control using MIDI. FM, additive and subtractive synthesis. Physical modeling and sound spatialization. Course project.

ECE 483 DSP System Design 3R-3L-4C F Prereq: ECE 380 and MA 381
Study of finite word length effects in DSP systems. Cascaded filter structures. Coefficient quantization, roundoff noise, scaling for overflow prevention. Discrete-time noise, filtering noise, power spectral density. Polyphase filtering, interpolation and decimation. Implementation and system design and test issues for a SSB communication system. Integral laboratory based on a fixed point programming project.

ECE 497 Special Topics in Electrical Engineering 1-4C arranged Prereq: Consent of instructor and department head
Topics of current interest to undergraduate students.

ECE 498 Undergraduate Projects 1-4C Arranged Prereq: Consent of instructor
Special design or research projects.

ECE CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

UNDERGRADUATE-GRADUATE COURSES

ECE 510 Error Correcting Codes 4R-0L-4C F (odd years) Prereq: Graduate standing and ECE 310, or ECE 310 with a grade of B or better, or consent of instructor
Coding for reliable digital communication. Topics to be chosen from: Hamming and BCH codes, Reed-Solomon codes, convolutional codes, Viterbi decoding, turbo codes, and recent developments, depending on interests of class and instructor. Mathematical background will be developed as needed.

ECE 511 Data Communications 4R-0L-4C F (even years) Prereq: Graduate standing and ECE 310 and MA 381, or ECE 310 and MA 381 with a grade of B or better in both courses, or consent of instructor
Design of digital communication systems. Autocorrelation function and power spectrum, vector space models of signals and noise, optimal receiver structures and performance, bandlimited channels and equalization, convolutional coding.

ECE 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing
Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor.
Cross-listed with BE 516, CHE 505, EP 510, and ME 516.

ECE 519 Advanced MEMS: Modeling and Packaging

ECE530 Advanced Microcomputers 3R-3L-4C S Prereq: Graduate standing and ECE 331 or ECE 230; or ECE 331 or ECE 230 with a grade of B or better; or consent of instructor
32-bit microcontroller architecture. Software development in both assembly language and C language. Hardware interfacing. Use of a real-time-operating system (RTOS). System-on-a-chip (SOC) hardware/software design using a field programmable gate array (FPGA) chip containing an embedded microcontroller cores. Software debugging tools. Integral laboratory.

ECE 531 Digital Test and Product Engineering 3R-3L-4C S Pre: Graduate standing and ECE230 Intro to Embedded Systems, ECE233 Intro to Digital Systems and ECE250 Electronic Device Modeling; or ECE230, ECE233, and ECE250 with grades of B or better in all three courses; or consent of instructor.
Industrial testing techniques for microcontrollers and other digital integrated circuits. Includes common digital system fault modeling, test generation, and design for testability in addition to memory testing strategies. Integral labs using an industrial grade automatic test environment (ATE).

ECE534 Advanced Signal and Power Integrity 4R-0L-4C W Prereq: Graduate Standing and ECE341, ECE342, or ECE343; or ECE341, ECE342, or ECE343 with a grade of B or better, or ECE342 with a grade of B or better, or consent of instructor
Signal and power integrity modeling and measurement in high-speed digital systems at IC, PCB, and chassis levels. High-frequency behavior of passive components and packages. Behavior and SPICE models of drivers and receivers. Lossy transmission lines and discontinuity characterization. Mixedmode s-parameters and other network parameters. Frequency and time-domain modeling of capacitive and inductive crosstalk. Differential signaling techniques; timing conventions. Synchronization. Signal equalization. Power plane noise and resonance. High-speed PCB design guidelines. Measurement techniques including time-domain reflectometry, vector network analyzer and impedance analyzer. PCB simulation. Full-wave simulations.

ECE 535 Design of Fault-Tolerant Systems 3R-3L-4C S Prereq: Graduate standing and CSSE 232 or ECE 333; or CSSE 232 with a grade of B or better, or ECE 333 with a grade of B or better; or consent of 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 Prereq: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor.
Electromagnetic radiation, antenna terminology and characteristics, dipole antennas, arrays, aperture antennas, measurements, computer-aided analysis, design projects and reports.

ECE541 Microwave/Millimeter-Wave Engineering 4R-0L-4C S Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor
Wave-guiding structures, microwave network analysis, scattering parameters, Z, Y and ABCD parameters, passive devices and components, design, fabrication, simulation and measurement of microwave devices and components, matching strategies, multi-conductor transmission lines and crosstalk.

ECE542 Advanced Electromagnetics 4R-0L-4C F Prereq: Graduate standing and ECE341, or ECE341 with a grade of B or better, or consent of instructor
Maxwell’s equations, EM field theorems, potential functions, power and energy, material properties, wave propagation, reflection and transmission, radiation, scattering, Green's functions, metamaterials and metamaterial-inspired structures, modeling & simulation, measurement technique.

ECE543 Mathematical Methods of Electromagnetics 4R-0L-4C Pre: Graduate Standing, or ECE341 with a grade of B or better, or consent of instructor
Perturbational and variational techniques, moment methods, integral equation and Wiener-Hopf techniques, development of computer programs.

ECE551 Digital Integrated Circuit Design 3R-3L-4C F Prereq: Graduate standing, or ECE333 with a grade of B or better, or consent of instructor
Design, performance analysis, and physical layout of CMOS logic. Custom and standard cell methodologies. Use of commercial CAD tools. Design issues such as interconnect, timing, and testing methods. Integral laboratory and project.

ECE552 Analog Integrated Circuit Design 3R-3L-4C W Prereq: Graduate standing and ECE351 and ECE380, or ECE351 and ECE380 with a grade of B or better in both courses, or consent of instructor
Design, performance analysis, and physical layout of analog integrated circuits. Focus on operational amplifier

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed. Same as BE541.

ECE 597 Special Topics in Electrical Engineering 4C Prereq: Consent of instructor

Professors Andrijcic, Downing, Hamasha, James, Kline, Schumacher and Stamper

EMGT ESC - Escalate Program Participant - 0C
Students participating in the Escalate entrepreneurship program will be enrolled in this zero credit section each quarter. The course will be graded S or U. A grade of S will be given for completing the required Escalate courses, attending required professional development activities, and completing required project activities. Only students in the Escalate cohort may enroll in this section.

EMGT100 Introduction to Entrepreneurship 4R-0L-4C
This course provides an overview of the principles of entrepreneurship and becoming an entrepreneur in today's society. Topics include opportunity identification, market investigation, product development, developing marketing and business plans, and understanding business, financial, and legal matters related to venture creation. Concepts from the lean startup and canvas tools will be applied.

EMGT152 Economic Thinking for Entrepreneurs 1R-0L-1C Corequ: SV151 or consent of instructor
During this course students discuss the economic implications of entrepreneurial actions.

EMGT330 Introduction to Engineering Management 4R-0L-4C Undergraduate Only
Surveys issues important to the management of engineering activities and technological organizations. Topics include such things as the relationship of engineering and technology to management disciplines, the functions of a technical manager, principles and techniques for quality processes, project management, process management, logistics, legal issues, ethics, human resources, communication and organizational behavior.

EMGT427 Project Management 4R-0L-4C Undergraduate Only
Presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, scheduling, task partitioning & communication, rework, and negotiation. Provides application experiences with these concepts through case analyses. Emphasizes typical problems and issues related to project management choices

EMGT461 Multidisciplinary, Entrepreneurial Design I: Capture the Vision 3R-XL-4CPre: Junior, Senior, or consent of instructor
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design disciplines to a specific project by using creativity techniques, identifying sustainable competitive advantages and appropriate intellectual property protection procedures. Uses project planning methods to estimate project size and assess risks, as well as other techniques to facilitate rapid product development. Provides experiences in communication, project retrospectives and design reviews. Completes the early stages of a team selected and conducted project in entrepreneurial design that has the approval of students' home department. Prerequisite: EMGT461 or consent of instructor.

EMGT463 Multidisciplinary, Entrepreneurial Design III: Deliver the Product 2R-XL-XC Pre: MG 462 or consent of instructor
Further examines and applies design process disciplines, including techniques such as system modeling, optimization, statistical analysis, design of experiments, FMEA (Failure Modes and Effects Analysis), robust design, simulation and process improvement. Describes key business concepts needed for a business plan and applies them to the team projects. Uses professional project approaches such as metrics, retrospectives, design reviews and proper documentation. Emphasizes team project work with home department approval of specific discipline related design activities and with practical applications of concepts in the realization of functional prototypes or systems. Concludes with written and oral presentations of team project reports. Prerequisite: MG 462 or consent of instructor.

EMGT486 Introduction to Supply Chain Management 4R-0L-4C Technical
Introduces and discusses traditional operations within supply chains including changes due to evolving technologies and globalization. Demonstrates relationships between suppliers, customers, and competitors and how they affect the entire manner in which organizations can efficiently globally integrate and optimize their manufacturing and business operations. Cross-listed with EMGT 586.

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Topics addressed include: market research methods, market segmentation, product positioning (4 Ps), pricing strategies, alliances, elasticity, advertising & brands, and the champion role. Student projects define a new product idea, apply course concepts to the development of that idea (segmentation, pricing, etc.) and present their analysis to the class. The course includes the 'NPDChallenge'simulation that demonstrates marketing issues an entrepreneur faces in developing a new product.

EMGT524 Production/Operations Management 4R-0L-4C Technical or Management
To provide an introduction to operations management for the technical manager including contemporary management principles and technical methods. Key focus topics include development of strategy in operations activities and the use of a business simulation exercise and project to illustrate class concepts.

EMGT525 Human Resources Management 4R-0L-4C Management Elective
Examines Human Resource Management for engineers who may or may not have direct reports (subordinates). Key focus topics include systematic changes that influence employees' behavior, attitudes, and performance throughout the employment lifecycle. Furthermore, we explore value-added HRM practices related to analyzing/designing work, recruiting and selection, training and development, evaluating performance, and the creation of positive employee relations in today's workplace.

EMGT526 Innovation Management & Forecasting 4R-0L-4C
This course introduces the concepts of innovation types (radical, incremental, disruptive, open), invention, and diffusion to identify patterns of technology change. Technology management strategies are suggested by an even blend of theory and case analysis. The course explores the impact of innovation on society, including long term trends in productivity, energy, and information technologies. Techniques used in technology forecasting (monitoring, growth curves, scenarios, analogy, Delphi, roadmapping, and simulation) are described & example forecasts are examined.

EMGT527 Project Management 4R-0L-4C Technical or Management
This course presents the major issues and techniques of project management. Topics include: project evaluation and selection, scope management, team building, stakeholder management, risk assessment, estimating, scheduling, Mythical Man Month, Critical Path & Critical Chain, task partitioning & communication, rework, and negotiation. Students apply these concepts in writing case analyses. Typical problems and success factors are discussed in relation to project management choices. Special issues encountered in virtual teams are discussed.

EMGT529 Organizational Behavior 4R-0L-4C
This course will introduce students to principles and theories related to management and organizational behavior. The goal is to transfer or develop knowledge and skills for high performance in a complex technical business environment requiring engineers to make and communicate sound decisions, and react appropriately to unanticipated events. The concepts and techniques for maximizing the effectiveness of engineers in the achievement of organizational and project goals are also emphasized. Topics include power, teaming, motivation, selection, and development while understanding individual characteristics, attitudes, and behaviors. Additionally, we will examine how the use of Emotional Intelligence (EI) will be useful to the advancement of organizations that are culturally diverse.

EMGT531 Economics for Technical Managers 4R-0L-4C Management
Applies economic analysis to the solutions of business problems. Emphasizes the economics of market and organizational structure, demand determinates, cost analysis, investment and strategy decisions, agency problems and ethics. Special reference is made to technology based organizations.

EMGT532 Technical Entrepreneurship 4R-0L-4C Management
Examines the principles and tools for innovation and entrepreneurship in technologically based businesses. Includes perspectives for both independent entrepreneurs and intrapreneurs. Develops basic concepts of business planning. Emphasizes a major group business plan based upon a technological innovation. May be used as a management core class.

EMGT533 Intercultural Communication 4R-0L-4C Management
This course presents the Constructivist theory of communication and its application. The culture concept is applied at ethnic (~70%) organizational and interpersonal levels. The course balances theory and application and students write analysis of videos to apply course concepts. Students use Spradley's Ethnoscience approach to conduct interviews and write an ethnography for their term paper. The course helps students to better: develop interpersonal relations, improve their interviewing skills, analyze cultures, and understand diversity across ethnic & gender differences. Concepts include: Culture Shock, Empathy, The Social Construction of Reality, Non Verbal Communication, High & Low Context cultures, M time & P time cultures.

EMGT534 Management Science 4R-OL-4C F (even years) Prereq: Senior or graduate standing

This class will introduce students to the art and science of systems architecting, where systems architecting refers to uncovering the fundamental structure of a system (functional, physical, logical, operational) defined in terms of system's elements, interfaces, processes, constraints, and behaviors that must operate under specific requirements and constraints. Focus will be placed on investigating the broader meaning of architectures, as they relate to organizations and businesses, in addition to engineered systems and products. Students will be introduced to heuristic and model-based approaches for systems architecting. Through case-studies and example problems in areas of production and manufacturing systems, intelligent transportation systems, social systems, and others, students will be able to apply the principles, processes and tools of systems architecting in order to structure and support the system development process of a balanced, well-integrated and socially and financially acceptable system.

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Covers fluid properties, fluid statics, fluid dynamics, including pipe flow, and turbomachinery. Stresses the control volume approach, Eulerian description of flow, and conservation principles (mass, momentum, and energy).

EM403 Advanced Mechanics of Materials 4R-0L-4C S Prereq: EM 203 or EM 204
Covers advanced topics in mechanics of deformable bodies and theories of failure. Introduces the theory of elasticity.

EM 406 Vibration Analysis 4R-0L-4C F Prereq: ES 205
Dynamic analysis of vibrating mechanical systems. Includes studies of single- and multiple-degrees-of-freedom, damped and undamped systems in both free and forced motion. Applications to vibration isolation and absorption, design of vibration measurement instrumentation, rotating unbalance, and torsional vibration of rotors.

EM 493 Selected Topics in Engineering and Technology

UNDERGRADUATE-GRADUATE COURSES

EM 501 Topics in Fluid Mechanics

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Prereq: PH405 or ECE250

Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher,Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

EP 280 Introduction to Nano-engineering 3.5R-1.5L-4C W
Scaling laws in small systems; electronics and photonics devices and systems, basics of quantum and statistical mechanics, nanomaterials and fabrication: examples of zero, one, two, and three dimensional nanostructures, carbon nanotubes, Nanoelectronics: basics of solid state physics; electron energy band, semiconductors, tunneling and quantum structures, molecular electronics, Nanophotonics in metals and semiconductors, surface plasmon resonance and applications, photonic bandgap crystals.

EP 290 Directed Study Credit arranged Prereq: Consent of instructor
Research for freshmen and sophomore students under the direction of a physics or optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 330 Material Failure 3R-3L-4C W Prereq: PH112
Principles of material failure; appearance, physical cause and mathematical description with emphasis on the materials used for micro-scale devices and assemblies. Failure types considered include Rupture, Fatigue, Creep, Corrosion, Electromigration, Electrical Overstress, Electrical Discharge and Thermal. Experiments illustrate the failure type and the machines used to study them. These include Electron, Optical and X-ray microscopes, Spectroscopy and Tension machines. A brief description of the working of each machine will be given.

EP 380 Nanotechnology, Entrepreneurship and Ethics 3.5R-1.5L-4C S
Scaling laws in small systems; mechanical, biological, fluidics, and thermal systems. Nanomaterials and nanofabrication. Nanomechanics: cantilever oscillation, atomic-force microscopy (AFM) and its applications, nano-biotechnology, machinery of cell, and molecular motors. Nanoscale optics, Nanoscale heat: conduction, convection, and blackbody radiation. Basics of fluidics, nanoscale fluidics and applications, entrepreneurship and ethics, concepts and tools in innovation and social impacts of nanotechnology.

EP 406 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic devises þ506

Prereq: PH405 or ECE250

characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation.

EP 408 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor
Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Cross-listed with EP 508.

EP 410 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing
Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Cross-listed with ME 416, ECE 416, and CHE405.

EP 411 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410 or equivalent course
Topics such as: Microlithography, design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Cross-listed with ECE 419, and CHE 419.

EP 415 Engineering Physics Design I 2R-6L-4C S Prereq: OE 280 or EP 280 & JR/SR standing Coreq: RH 330
Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with OE 415.

EP 416 Engineering Physics Design II 2R-6L-4C F Prereq: EP 415
Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with OE 416.

EP 417 Engineering Physics Design III 2R-6L-4C W Prereq: EP 416
Continuation of EP 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with OE 417.

EP 470 Special Topics in Engineering Physics 2-4 Credits Prereq: Consent of instructor
Lectures on special topics in engineering physics.

EP 490 Directed Study Credit arranged Prereq: Consent of instructor
Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn up to a maximum of 2 credits for meeting the graduation requirements. The student must make arrangements with a faculty member for the research project prior to registering for this course.

EP 506 Semiconductor Devices and Fabrication 3R-3L-4C W Prereq: PH405 or ECE250
Metal-semiconductor interfaces; photoresist and photolithography; thin film deposition; design and fabrication of semiconductor diodes; characterization of process diodes and transistors; MOSFETS; optoelectronic 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 507 Semiconductor Fabrication and Characterization 2R-6L-4C F Prereq: PH405 or consent of instructor
Fabrication and characterization of micro/nanoelectronic devices; Semiconductor devices; Oxidation, ion implantation, etching, deposition, lithography, and back-end processing; Process integration of various technologies, including CMOS, double poly bipolar junction transistor, and GaAs MESFET. Process and device simulators illustrate concepts introduced in class. Modern tools/techniques for both bulk- and thin-film characterization; Laboratory is an integral component of this class. Students work in teams to fabricate a multi-

junction semiconductor device, using various techniques which include photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Circuits are used to carry out performance evaluation. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both EP 407 and EP 507.

EP 508 Microsensors 3R-3L-4C S Prereq: JR or SR standing, and consent of instructor
Introduction to solid state materials and conventional silicon processing. Measurement of signals from resistance- and capacitance-based transducers; sensor characteristics, calibration and reliability. Examples of microsensors: thermal, radiation, mechanical, chemical, optical fibers, and biological. Students must do additional project work on a topic selected by the instructor. Cross-listed with EP 408.

EP 510 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing
Properties of silicon wafers, wafer-level processes, vacuum systems, thin-film deposition via PVD, dry and wet etching, photolithography, surface and bulk micromachining, process integration, MEMS applications: heat actuators, capacitive accelerometer, DLP, bio-sensor, and pressure sensor. Students must do additional project work on a topic selected by the instructor. Cross-listed with BE 516, CHE 505, ECE 516, and ME 516.

EP 511 Advanced topics in MEMS 3R-3L-4C F Prereq: EP410/510 or consent of instructor
Topics such as: Microlithography. Design process, modeling; analytical and numerical. Use of software for layout design and device simulation. Characterization and reliability of MEMS devices. MEMS and microelectronic packaging. Introduction to microfluidic systems. Applications in engineering, biomedicine, and chemistry. Students must do additional project work on a topic selected by the instructor. Cross-listed with ME 519, ECE 519, and CHE 519.

EP CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

EP Electives:
Courses from any science or engineering department which are of relevant level to the area concentration. If not in the area concentration, courses should be 300 level or above. It is recommended that students take a sequence of classes from the area concentration. This will fulfill engineering science elective in their engineering curriculum.

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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,
-

GEOL 270 Geology for Engineers and Environmental Scientists 4R-0L-4C Prereq: CHEM 111
Physical, historical, chemical, structural and environmental aspects of earth science addressed from an engineer's or environmental scientist's perspective. The course includes study of minerals and rocks, investigation of geologic hazards, an introduction to rock and soil mechanics, case studies, and interpretation of topographic maps, geologic maps and aerial photographs.

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Course Descriptions

Mathematics

Professors Broughton, Bryan, Butske, Carlisle, N. Chenette, Eichholz, Evans, Finn, Goulet, Graves, Green, Grimaldi, Holden, A. Holder, L. Holder, Isaia, Langley, Leader, McSweeney, Panaggio, Rader, Reyes, Rickert, Selby, Shibberu, Tabing and Tarrant.

MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C Prereq: At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.
A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen. Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

MA 111 Calculus I 5R-0L-5C F,W
Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

MA 112 Calculus II 5R-0L-5C F,W,S Prereq: MA111
Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

MA 113 Calculus III 5R-0L-5C F,W,S Prereq: MA112
Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

MA 190 Contemporary Mathematical Problems 2R-0L-2C S Co-requisite: MA113
A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and applications, famous problems, and outstanding problems of great significance.

MA 200 Career Preparation 1R-0L-1C W
This course is for mathematics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200 and PH200.

MA 211 Differential Equations 4R-0L-4C F,W, S Prereq: MA113
First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and

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

engineering.

MA 212 Matrix Algebra and Systems of Differential Equations 4R-0L-4C F,W,S Prereq: MA113
Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

MA 223 Engineering Statistics I 4R-0L-4C F,W,S Prereq: MA112
This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to 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 23.03ohof lineardQeere1 aS Prereq: rDC 7.6928 0 0 7.6928 23.6103Qeere1 9 Tm 20.06andard deviation/v stur
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generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

MA 382 Introduction to Statistics with Probability 4R-0L-4C F Prereq: MA381
This is an introductory course in statistical data analysis and mathematical statistics.
Topics covered include descriptive statistics, Sampling distributions (including the entral Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

MA 383 Engineering Statistics II 4R-0L-4C F Prereq: MA223 or MA382
Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

MA 385 Quality Methods 4R-0L-4C S Prereq: MA223 or MA382
Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual’s charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 385

MA 386 Statistical Programming 4R-0L-4C Prereq: previous programming course and either MA223 or MA382
Database management and statistical analysis using SAS and possibly, R/S+. Topics will include database management (including SQL), data step programming, macro programming, standard data analysis methods (from MA223 or higher level courses), and coding of advanced and/or computationally intense modern algorithms, e.g., bootstrapping and Monte Carlo methods.

MA 387 Statistical Methods in Six Sigma 4R-0L-4C Prereq: MA223 or MA382
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Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

MA 466 Introduction to Functional Analysis 4R-0L-4C Arranged Prereq: MA366
An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

MA 470 Topics in Algebra 4R-0L-4C Arranged Prereq: instructor permission
An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

MA 471 Linear Algebra II 4R-0L-4C S (even years) Prereq: MA371 or MA373
Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

MA 473 Design and Analysis of Algorithms 4R-0L-4C F Prereq: CSSE230 and MA375
Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

MA 474 Theory of Computation 4R-0L-4C W Prereq: CSSE 230 and MA 375
Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

MA 475 Topics in Discrete Mathematics 4R-0L-4C Arranged Prereq: MA375
An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

MA 476 Algebraic Codes 4R-0L-4C S (odd years) Prereq: MA375 or consent of instructor
Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

MA 477 Graph Theory 4R-0L-4C S (even years) Prereq: MA375 or consent of instructor
An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

MA 478 Topics in Number Theory 4R-0L-4C Arranged Prereq: MA 378 or MA375 or consent of the instructor
Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

MA 479 Cryptography 4R-0L-4C S Prereq: CSSE220 and MA275
Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

MA 480 Topics in Probability or Statistics 4R-0L-4C Arranged Prereq: instructor permission
An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

MA 481 Mathematical Statistics 4R-0L-4C W (even years) Prereq: MA382, or MA381 and consent of instructor
An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

MA 482 Bioengineering Statistics 4R-0L-4C S Prereq: MA223 or MA382
Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

MA 485 Applied Regression Analysis and Introduction to Time Series 4R-0L-4C W (odd years) Prereq: MA212 and either MA223 or MA382
Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

MA 487 Design of Experiments 4R-0L-4C W (even years) Prereq: MA223 or MA382
Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

MA 490 Topics in Mathematics Variable credit Prereq: Consent of instructor
This course will cover advanced topics in mathematics not offered in listed courses.

MA 491 Introduction to Mathematical Modeling 2C F Prereq: Senior Standing or permission of the instructor
An introduction to the process of mathematically modeling a problem, including data collection, defining the

Professors Adams, Bernal, Brackin, Burchett, Cantwell, Chambers, Cornwell, Cunningham, Fine, Fisher, Gibson, Haan, Jones, Kawano, Layton, Lui, McCormack, Mayhew, Mech, Mirth, Moorhead, Moseley, Olson, Onyancha, Purdy, Richards, Sanders, Stamper, White and Winck.

ME 123 Computer Programming 4R-0L-4C F,W,S Prereq: ME/PHOE major or permission of instructor
Software tools and engineering processes for mechanical engineers. Topics may include: structured programming (Matlab), simulation of rigid body motion, presentation software, and spreadsheets. Introduction to teaming and creativity.

ME 193 Selected Topics in Design Hours as assigned. Maximum 4 credits per term. F,W,S
Selected student design projects. May include testing and/or computer aided design.

ME 293 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Sophomore class standing
Selected student design projects. May include testing and/or computer aided design.

ME 301 Applications of Thermodynamics 4R-0L-4C F,W Prereq: ES 201 with a grade of C or better or CE205
Extend the conservation and accounting framework to examine energy-conversion systems. Topics include thermodynamic properties of pure substances, gas mixtures, exergy analyses, power and refrigeration cycles, psychrometric processes, combustion, and propulsion.

ME 302 Heat Transfer 4R-0L-4C S,F Prereq: MA 211 and ES 202 or CHE 301 or EM 301
Introduces the basic modes of heat transfer, heat transfer properties, steady and unsteady one-dimensional heat conduction, free and forced convection, radiation and heat exchangers. Other topics may include numerical methods and boiling and condensation.

ME 305 Introduction to Aerospace Engineering 4R-0L-4C S Prereq: ES 202
Application of fundamental engineering concepts to aerospace systems. Aircraft performance and stability. Physical properties of the standard atmosphere. Aerodynamics of the airplane including lift, drag and pitching moment estimation. Introduction to orbital mechanics.

ME 317 Design for Manufacturing 3R-0L-3C W Prereq: EM 104
This is an introductory course that examines the interactions between design and manufacturing from the designer's point of view. Common manufacturing processes will be introduced and design guidelines will be developed for each process. The successful student will leave this class with an appreciation that a designer must consider the method of manufacture during the design process to ensure that a product is functional, economically viable, and safe.

ME 318 Material Processing in Manufacturing 4R-0L-4C Prereq: ME 328
An introductory course in the control of the properties of materials during manufacturing. Covers the interrelationship between material properties and the principal manufacturing processes like hot and cold working, casting, welding, heat treating and machining. Emphasizes the importance of considering manufacturability when making material selection decisions in design.

ME 321 Measurement Systems 3R-3L-4C W,S Prereq: EM 103, ES 205, MA 223

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Army ROTC (Military)
Biology & Biomedical Engineering
Biomathematics
Chemical Engineering
Chemistry and Biochemistry
Civil Engineering
College & Life Skills
Comp09 -64.37&omng, heaside& Softwaprog
College & Ecisireerin& .37&omng,g
College & E

Fundamentals of measurement systems in mechanical engineering including transducer operation, signal conditioning, data reduction, and presentation of results. Transducer and measurement system characteristics including resolution, sensitivity, loading, time response, and frequency response. Operating principles of basic instrumentation for measurement of mechanical quantities such as force, torque, pressure, temperature, and flow. Topics include uncertainty analysis, data analysis, calibration, data acquisition, presentation of results, and an introduction to experiment design.

ME 323 Numerical Methods in Engineering 1R-3L-2C W,S Prereq: ME 123, or CSSE 120, MA 212
Engineering problems often lead to analytically intractable equations. This course combines structured programming and applied numerical methods to obtain approximate engineering solutions. Strategies include root finding, numerical integration, finite difference, initial value and boundary value problems. Matlab is used as the programming language for solving iterative problems numerically.

ME 328 Materials Engineering 4R-0L-4C W Prereq: CHEM 111
Introduces properties of metals, ceramics, polymers, and composites. Relates material processing to properties through underlying material structure. Overviews the materials available to engineers and discusses applications and material selection.

ME 380 Creative Design 4R-0L-4C W Prereq: Permission of instructor
Emphasis on the creative process in engineering design. Students will develop their design capability by exploring various conceptual blocks, using creative enhancement techniques and participating in on-the-spot design.

ME 393 Selected Topics in Design. Hours as assigned. Maximum 4 credits per term. F,W,S Prereq: Junior class standing
Selected student design projects. May include testing and/or computer aided design.

ME 397 Special Topics in Mechanical Engineering 4R-0L-4C
Topics of current interest in mechanical engineering at the 300-level.

ME 401 Foundations of Fluid Mechanics 3R-3L-4C

energy. Surveys the energy availability of these sources and life cycle cost and present value used to evaluate

flow with friction and heat transfer.

ME 511 Numerical Methods for Dynamic Systems Analysis 4R-0L-4C Prereq: ES 205 and ME 323
Applications of approximate numerical solution techniques, including the finite element method, to the analysis of dynamic, continuous systems. Introduction to variational principles in mechanics for purposes of formulating governing equations of motion.

ME 512 Light Weight Structures 4R-0L-4C S Prereq: MA 212 and EM 203 or EM 204
Applies the principles of mechanics to the structural analysis of mechanical and aerospace components. Covers stress tensors, shear flow in open and closed sections, beam columns, unsym-metrical bending. Castigliano's theorem, statically indeterminate structures , thin walled pressure vessels, introduction to elasticity.

ME 513 Environmental Noise 4R-0L-4C F Prereq: Senior class standing
Introduces noise and its sources as a potential public health hazard. Covers the basics of sound propagation relating to noise measurement and analysis. Emphasizes effects on humans and the environment. Covers methods of noise and vibration control and abatement including absorption, enclosures, vibration isolation, damping, and mufflers. Team projects involving noise measurement and reduction are required.

ME 516 Introduction to MEMS: Fabrication and Applications 3R-3L-4C S Prereq: JR or SR standing
Properties of silicon wafers; wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS applications: capacitive accelerometer, cantilever and pressure sensor. Cross-listed with EP 510, ECE 516, CHE 505, and BE 516.

ME 518 Advanced Kinematics 4R-0L-4C S Prereq: ME 403
Considers the analysis, design, and simulation of planar and spatial mechanisms. The mechanisms examined are parallel manipulators, serial manipulators, and compliant mechanisms. These mechanisms are analyzed for

Fuzzy logic controllers. Genetic algorithm for optimization and turning of controllers including fuzzy logic control.

ME 547 Visualizing Data 4R 0L 4C. Prereq: Graduate standing and instructor consent.
Same as ME 447 with the added requirement that the course is open only to graduate students having a graduate project or thesis generating quantitative data that the course instructor has agreed meets the 500 level course objectives.

ME 550 Combustion 4

MDS 401 Independent Project/Research Opportunities Seminar 1R-0L-1C F,W,S Prereq: Permission of instructor

Companion seminar for students participating in the Independent Project/Research Opportunities Program. Students attend an organizational seminar, attend one additional IPROP seminar during the quarter, complete first week and tenth week surveys, acknowledge their sponsor, and generate publicity graphics. Students present their work as a poster at a tenth week End of Quarter Symposium. This course may not be used as credit toward any degree program. This course is given Pass/Fail.

MDS 402 Seminar in Sustainability 2R-0L-2C Pre: Junior class standing and approval of certificate advisors

Provides students with the opportunity to examine, analyze, and reflect upon sustainability and sustainable engineering projects. Course work includes weekly readings and discussions, individual essays, and in-class and public presentations. Enrollment is open to all students, with first priority given to those pursuing the Certificate in Sustainability Studies. Permission to enroll is contingent upon students' previous sustainability

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Professors Bunch, Ditteon, Duree, Granieri, Joenathan, E. Kirkpatrick, S. Kirkpatrick, Kirtley, Leisher, Letfullin, Liptak, McInerney, Moloney, Siahmakoun, Syed, and Wagner.

NOTE: In courses which include a laboratory, satisfactory completion of the laboratory work is required in order to pass the course.

OE 171 Photography and Holography 2R-0L-2C F
Introduce students to basic knowledge of optics, principles and operation of a camera, shutters, films, and film development, color photography. Basic understanding of interference of waves, concept of holography, properties of various holograms, application of holography, and each student makes an individual hologram that can be seen in sunlight.

OE 172 Lasers and Fiber Optics 2R-0L-2C S

OE 393 Fiber Optics and Applications 3.5R-1.5L-4C W (every other year) Prereq: OE 295 & PH 316 or ECE 341 or consent of instructor
Basic dielectric waveguide equations; wave optics and ray optics; step-index and graded-index fibers; single mode and multi-mode fibers; mode cutoff conditions; numerical aperture; fabrication of optical fibers; fiber measurements; fiber cable designs; source coupling, splices and connectors; fiber optic sensors; fiber optic components and systems. Relevant laboratory experiments.

OE 395 Optomechanics & Optical Engineering Lab 2R-6L-4C F Prereq: PH 292, OE 280, and OE 295
Design, assembly, and alignment of bench top optical systems. Introduction to experimental techniques in optics. Data collection and analysis. Relevant lecture topics including principles of opto-mechanical design, fold mirrors and prisms, lens and mirror mounting, kinematic mounts, precision adjustments and control.

OE 415 Optical Engineering Design I 2R-6L-4C S Prereq: OE 280 or EP 280 and JR/SR standing Coreq: RH 330
Principles of design. Codes of ethics appropriate to engineers. Case studies related to optical engineering and engineering physics professional practice, teamwork, contemporary issues, patents and intellectual property. Team-oriented design project work on selected topics in optical engineering and engineering physics. Introduction to product development practices, product research, planning and project management. Preliminary design of a product and product specifications. Deliver a design document specific to customer needs and constraints. Cross-listed with EP 415.

OE 416 Optical Engineering Design II 2R-6L-4C F Prereq: OE 415
Team-based capstone design project following structured design processes and utilizing knowledge gained from prior coursework. Project planning and budgeting, development of product/process specifications, application of engineering standards, system design and prototyping subject to multiple realistic constraints (cost, schedule, and performance). Formal midterm design review. Deliver initial statement of work and interim technical report. Laboratory activities supporting the formal design process. Cross-listed with EP 416.

OE 417 Optical Engineering Design III 2R-6L-4C W Prereq: OE 416
Continuation of OE 416. System design and prototyping, performance testing, and data analysis. Formal midterm design review. Demonstration of a functional prototype. Deliver oral presentation and final technical report. Cross-listed with EP 417.

OE 434 Non-Imaging Optics 4R-0L-4C S (every other year) Prereq: OE 295
Lighting, illumination, and solar concentration systems. Radiometry and photometry for illumination, etendue, and concentration. Color coordinates, color vision, and color measurements. Sources, light transfer components, and systems evaluation. Introduction to design methods (edge-ray, compound parabolic concentrator, tailored reflector). Design examples and case studies.

OE 435 Biomedical Optics 4R-0L-4C W Prereq: PH 113 and MA 212
Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Cross-listed with BE 435.

OE 437/ECE 480 Introduction to Image Processing 3R-3L-4C W Prereq: MA 212
Basic techniques of image processing. Discrete and continuous two dimensional transforms such as Fourier and Hotelling. Image enhancement through filtering and histogram modification. Image restoration through inverse filtering. Image segmentation including edge detection and thresholding. Introduction to image encoding. Relevant laboratory experiments. Cross-listed with ECE 480.

OE 450 Laser Systems and Applications 3.5R-1.5L-4C S Prereq: PH 292 and MA 212
Ray transfer matrix methods, Gaussian beam propagation, and beam quality. Optical resonators and stability, longitudinal and transverse modes. Stimulated emission, population inversion, rate equations, gain and threshold. Q-switching and mode-locking. Applications and types of lasers. Laser safety and relevant laboratory experiments.

OE 470 Special Topics in Optical Engineering 2-4 Credits Prereq: Consent of instructor
Lectures on special topics in optics.

OE 480 Optical System Design 4R-0L-4C F Prereq: OE 280
Review of geometrical optics and exact ray tracing. Chromatic and monochromatic aberrations. Image quality assessment, spot size, point spread function, Strehl ratio, and modulation transfer function. Classical lens design and design of various imaging, non-imaging, and diffractive optical systems. First-order layout, computer-based optimization, tolerancing, and manufacturing considerations.

OE 490 Directed Research Credit arranged Prereq: Consent of instructor
Research for junior and senior students under the direction of a physics and optical engineering faculty member. May earn a maximum of 8 credits between PH/OE 290 and PH/OE 490 for meeting graduation requirements. Maximum of 4 credits per term. The student must make arrangements with the faculty member for the research project prior to registering for this course.

OE 493 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S (every other year) Prereq: OE 393
Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties: dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments.

OE 495 Optical Metrology 3.5R-1.5L-4C W Prereq: OE 280 and OE 392 Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments.

OE 497, OE 498, OE 499 Senior Thesis 1-2C F,W,S Prereq: Consent of PHOE faculty
Literature search, research proposal preparation, and laboratory project work. This sequence is designed to

OE 585 Electro-Optics and Applications 3R-3L-4C W Prereq: PH 292, PH 316 and SR standing or GR standing
Optical wave propagation in anisotropic media. Normal surface and the index ellipsoid. Double refraction. Optical activity and Faraday rotation. Pockels and Kerr effects. Electrooptic modulators. Acousto-optic effect. Modulators and scanners. Introduction to nonlinear optics. Second-harmonic generation and frequency doubling. Relevant laboratory experiments.

OE 592 Fourier Optics and Applications 3.5R-1.5L-4C W Prereq: OE 392 and SR standing or GR standing
Two-dimensional linear systems. Scalar diffraction theory, Fresnel & Fraunhofer diffraction. Coherent optical systems analysis. Frequency analysis of optical imaging systems. Spatial filtering and analog optical information processing. Wavefront reconstruction and holography. Relevant laboratory experiments.

OE 593 Fundamentals of Optical Fiber Communications 3.5R-1.5L-4C S (every other year) Prereq: OE 393 and SR standing or GR standing
Analysis and design of common fiber optic communication systems and optical networks. Transmission penalties, dispersion, attenuation. Optical transmitters and receivers: fundamental operation and noise. Intensity and phase modulation. Optical amplification: types of amplifiers, noise and system integration. Point-to-point links: power budget and rise-time analysis. Performance analysis: BER and eye diagrams. WDM concepts and components: multiplexers, filters, common network topologies. Non-linear effects in fibers. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 493 and OE 593.

OE 594 Integrated Optics 4R-0L-4C F Prereq: OE 393 and SR standing or GR standing
Theory of dielectric optical waveguides. Waveguide modes. Coupled-mode formalism and periodic structures. Input and output coupling of optical beams to planar structures. Waveguide losses. Phase, frequency and polarization modulators. Waveguide gratings, electro-optic modulators, and switching. Applications of integrated optics.

OE 595 Optical Metrology 3.5R-1.5L-4C W Prereq: OE280, OE392 or SR/GR standing or consent of instructor; Coreq OE480
Geometrical test methods (refractometers, knife edge, Ronchi, Wire, Hartmann). Review of interference and coherence. Third-order aberrations, Zernike polynomials, and fringe analysis. Interferometers (Newton, Fizeau, Twyman-Green, and shearing), fringe localization, and phase shifting. Holographic, Moire, photoelastic and speckle interferometry. Applications of optical metrology. Relevant laboratory experiments. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 495 and OE 595.

OE 599 Thesis Research
Graduate students only. Credits as arranged; however not more than 12 credits will be applied toward the requirements for the MS (OE) degree.

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sections, bifurcation plots, power spectra, Lyupunov exponents, and computer simulation of chaotic systems.

PH 231 Observational Astronomy 1R-3L-2C F Prereq: MA 111, and PH 111 or EM 120
Celestial coordinates; basics of celestial mechanics; electromagnetic radiation, atomic structure, spectra, blackbody radiation; telescopes and detectors; quantitative observational work using modern telescopes and detectors.

PH 235 Many-Particle Physics 3.5R-1.5L-4C F Prereq: PH 111 or Coreq: EM 202; and Coreq: MA 112

make arrangements with a physics and optical engineering faculty member for the research project prior to registering for this course.

PH 497, PH 498, PH 499 Senior Thesis 2-4C F,W,S Prereq: Consent of PHOE faculty
Literature search, research proposal preparation, and laboratory project work with a total number of 8 credit hours over the three quarter sequence. This sequence is designed to result in a completed senior thesis.

PH CPT Curricular Practical Training (CPT) 1R-0L-1C Prereq: Consent of Department Head
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

GRADUATE COURSES

Note: SR/GR standing is required for enrolling in the following 500-level courses.

PH 505 Semiconductor Materials and Devices I 3R-3L-4C F Prereq: PH 113 or PH 255 or PH 265
Material structure electronic levels and energy bands; semiconductor doping; optical and electronic material characteristics; p-n junction and diode characteristics; bipolar junction transistor; basics of device fabrication. Laboratories on X-ray and Scanning Electron Microscope investigations, device characteristics and a three-week design project on production and testing of thin films. Students must do additional project work on a topic selected by the instructor. Cross-listed with PH 405.

PH 512 Methods of Mathematical Physics 4R-0L-4C Arranged
Ordinary and partial differential equations, linear vector spaces, matrices, tensors. Strum-Liouville theory and eigenvalue problems, special functions, function of a complex variable, theory of groups, linear integral equations.

PH 514 Quantum Mechanics 4R-0L-4C Arranged
Development of quantum mechanical theory to the present time. Examples from spectroscopy, chemistry, nuclear physics.

PH 530 Advanced Acoustics 4R-0L-4C Arranged Prereq: PH 404
Waves in solids, electrodynamics and piezoelectric sound transducers, ultrasonics. Architectural acoustics. Underwater sound.

PH 537/ECE 582 Advanced Image Processing 3R-3L-4C S Prereq: CSSE 220 or CSSE221, and ME 323 or ECE 380 or consent of instructor; MA 212
Introduction to color image processing and image recognition. Morphological methods, feature extraction, advanced segmentation, detection, recognition and interpretation. Integral laboratory. Same as ECE 582.

PH 538 Introduction to Neural Networks 3R-3L-4C Arranged Prereq: SR/GR standing
Classifiers, linear separability. Supervised and unsupervised learning. Perceptrons. Back-propagation. Feedback networks. Hopfield networks. Associative memories. Fuzzy neural networks. Integral laboratory.

PH 540 Computer Physics 3R 3L 4C Arranged Prereq: Consent of instructor
Exploration of physics by simulation including planetary motion, waves, chaos, cellular automata and fractals; application of numerical methods of differentiation and integration; computer hardware and machine language as it affects laboratory use; curve fitting and smoothing of data.

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In a globally competitive environment, the need to rapidly transition from an innovative idea to a viable product necessitates that 21st Century engineers and scientists