DEPARTMENT AND PROGRAM DESCRIPTIONS

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MISSION STATEMENT
The Aerospace Program at WPI aims to graduate students with a comprehensive education that will enable them to establish productive careers in the aerospace industry, government, or academia.

PROGRAM EDUCATIONAL OBJECTIVES
The aerospace engineering program seeks to impart to our students strong technical competence in fundamental engineering principles along with specialized competence in aeronautical and astronautical topics. At the same time the program seeks to nourish a student’s creative talents through research opportunities, with the goal to develop a personal high standard of excellence and professionalism. Finally, the program seeks to provide an appreciation of the role of the aerospace engineer in society.

PROGRAM OUTCOMES
Graduating students should demonstrate that they attain the following:

• an ability to apply knowledge of mathematics, science, and engineering
• an ability to design and conduct experiments, as well as to analyze and interpret data
• an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
• an ability to function on multi-disciplinary teams
• an ability to identify, formulate, and solve engineering problems
• an understanding of professional and ethical responsibility
• an ability to communicate effectively
• the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
• a recognition of the need for, and an ability to engage in lifelong learning
• a knowledge of contemporary issues
• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
• knowledge covering one of the areas - aeronautical engineering or astronautical engineering - and, in addition, knowledge of some topics from the area not emphasized
• design competence that includes integration of aeronautical or astronautical topics

Program Distribution Requirements for the Aerospace Engineering Major

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9) students wishing to receive a Bachelor degree in “Aerospace Engineering”, must satisfy additional distribution requirements. These requirements apply to 10 units of study in the areas of mathematics, basic sciences, aerospace engineering science and design.

REQUIREMENTS
1. Mathematical and Basic Sciences
2. Engineering Science and Design (Includes MQP)

NOTES:
1. Must include a minimum of 5/3 units of mathematics including differential and integral calculus, and differential equations.
2. Must include a minimum of 3/3 units in physics including introductory electricity and magnetism, and intermediate mechanics.
3. Must include 2/3 units in chemistry including topics in thermodynamics.
4. Must include 6/3 units in fluids and propulsion with topics in heat transfer, incompressible and compressible fluid dynamics, subsonic and supersonic aerodynamics, airbreathing and rocket propulsion.
5. Must include 4/3 units in materials and structures, with topics in materials science, stress analysis, and aerospace structures.
6. Must include 4/3 units in dynamics and control with topics in orbital mechanics, control theory, guidance, navigation, communications, and aircraft or spacecraft dynamics and control.
7. Must include 1/3 units in aerospace systems design that integrates either aeronautical or astronautical engineering topics.
8. Must include 1/3 Unit of Capstone Design Experience.

MAJOR QUALIFYING PROJECTS
The Aerospace Engineering Program provides opportunities, resources and organization for MQPs in aeronautics or astronautics. MQPs are conducted in the research laboratories of the Aerospace Engineering program, in conjunction with industry or government research centers. MQPs are often conducted in collaboration with graduate students and serve as a vehicle for integration of undergraduate studies with research in state of the art technologies. Students are encouraged and often supported to participate in the AIAA Northeast Student Conference, other professional meetings organized by AIAA as well as national design competitions.

Aeronautes
These project opportunities are for students interested in aircraft and/or aircraft systems design. Central activity in these projects is the design, construction, and testing of remotely piloted aircraft and micro aerial vehicles. Other projects may include topics in aerodynamics, controls, wake flows, and gas dynamics.

Astronautics
These project opportunities are for students interested in space science and engineering. Topics include electric propulsion, micro-propulsion, and control of space structures.
# Aerospace Engineering Program Chart

## 12/3 Units of General Education Activities

- **6/3 Units H&A Sufficiency**: See WPI Requirements
- **3/3 Unit Interactive Qualifying (IQP) Project**: See WPI Requirements
- **2/3 Unit Social Science**: See WPI Requirements
- **1/3 Unit Physical Education**: See WPI Requirements

## 3/3 Units of Free Elective

- **3/3 Units Free Elective**: See Catalog

## 12/3 Units of Mathematics and Basic Science

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>Physics</th>
<th>Chemistry</th>
<th>Electives</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/3 Units Required</td>
<td>3/3 Units Required</td>
<td>2/3 Units Required</td>
<td>2/3 Units Required</td>
</tr>
<tr>
<td>MA 1021 Calculus I</td>
<td>PH 1110 or PH 1111 General Physics- Mechanics</td>
<td>CH 1010 Chemistry I or</td>
<td>Student Selected Courses from the General Category of Mathematics and Basic Science</td>
</tr>
<tr>
<td>MA 1022 Calculus II</td>
<td>PH 1120 or PH 1121 General Physics-Electricity &amp; Magnetism</td>
<td>CH 1020 Chemistry II</td>
<td></td>
</tr>
<tr>
<td>MA 1023 Calculus III</td>
<td>PH 2201 Intermediate Mechanics I</td>
<td>CH 3510 Chemical Thermodynamics</td>
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<tr>
<td>MA 1024 Calculus IV</td>
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<td></td>
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<tr>
<td>MA 2051 Ordinary Differential Equations</td>
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</table>

## 18/3 Units of Engineering Science and Design (Note 1)

<table>
<thead>
<tr>
<th>Fluids and Propulsion</th>
<th>Materials and Structures</th>
<th>Dynamics and Control</th>
<th>Systems Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/3 Units Required</td>
<td>4/3 Units Required</td>
<td>4/5 Units Required</td>
<td>1/3 Units Required</td>
</tr>
<tr>
<td>ES 3003 Heat Transfer</td>
<td>ES 2001 Intro to Materials</td>
<td>ES 3011 Control Engineering I</td>
<td>ME 4770 Aircraft Design or</td>
</tr>
<tr>
<td>ES 3004 Fluid Mechanics</td>
<td>ES 2502 Stress Analysis</td>
<td>ME 2713 Astronautics</td>
<td>ME 4771 Spacecraft and Mission</td>
</tr>
<tr>
<td>ME 3602 Incompressible Fluid Dynamics</td>
<td>ME 3712 Aerospace Structures</td>
<td>ME 4733 Guidance, Navigation and Communications</td>
<td></td>
</tr>
<tr>
<td>ME 3410 Compressible Fluid Dynamics</td>
<td>ME 4718 Advanced Materials with Aerospace Applications</td>
<td>ME 4723 Aircraft Dynamics and Control or</td>
<td></td>
</tr>
<tr>
<td>MÉ 3711 Aerodynamics</td>
<td></td>
<td>ME 4713 Spacecraft Dynamics and Control</td>
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<tr>
<td>ME 4710 Gas Turbines for Propulsion and Power Generation or ME 4719 Rocket Propulsion</td>
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The courses above can be replaced by other equivalent courses, with the approval of the AE Program Committee

## 3/3 Units of Engineering Science and Design

- **Major Qualifying Project (MQP)**

Note 1: 1/3 unit of an activity must be in Capstone Design (can be satisfied with MQP, ME 4770, ME 4771)
AIR FORCE AEROSPACE STUDIES

LT COL TERRENCE A. LEARY, HEAD
PROFESSOR: Lt Col T. Leary
ASSISTANT PROFESSORS: Maj. R. Davis, Capt. D. Richards

MISSION
The mission of AFROTC is to produce leaders for the Air Force and build better citizens for America. Its vision is to be “a highly successful organization, respected throughout the Air Force, the educational community and the nation.”

EDUCATIONAL OBJECTIVES:
Students who successfully complete the AFROTC program will have:
1. An understanding of the fundamental concepts and principles of Air and Space.
2. A basic understanding of associated professional knowledge.
3. A strong sense of personal integrity, honor, and individual responsibility.
4. An appreciation of the requirements for national security.

AIR FORCE ROTC PROGRAMS
There are two traditional routes to an Air Force commission through Air Force ROTC. Entering students may enroll in the Air Force Four-Year Program. Students with at least two academic years remaining in college may apply for the Two-Year Program. However, there are opportunities for Freshmen, Sophomores, Juniors, and in some cases Seniors and Graduate Students. Please check with the AFROTC Detachment Staff for these special circumstances.

FOUR-YEAR PROGRAM
The more popular and preferred program is the traditional Four-Year Program. To enroll, simply register for Air Force Aerospace Studies in the fall term of the freshman year in the same manner as other college courses. There is NO MILITARY OBLIGATION for the first two years of Air Force ROTC unless you have an Air Force ROTC scholarship.

The first two years are known as the General Military Course (GMC). Classes meet once per week and are required for freshmen and sophomores.

Individuals who successfully complete the GMC compete nationwide for entry into the Professional Officers Course (POC). POC classes meet three hours per week and are required for all juniors and seniors. Officer Candidates enrolled in the POC and on scholarship receive a nontaxable subsistence allowance of up to $400 each month.

Qualified Officer candidates will attend the Air Force ROTC field-training program for four weeks between their sophomore and junior years.

TWO-YEAR PROGRAM
The Two-Year Program is available for college students with two years of undergraduate or graduate study remaining. Applicants must apply for the program no later than the beginning of Term C (spring semester) preceding those two final years. The applicant will take the Air Force Officer Qualifying Test, will be given a physical examination at no expense, and will meet a selection board.

Applicants for the Two-Year Program will attend the Air Force ROTC field training for six weeks instead of four at an Air Force base prior to their entry into the Professional Officer Course (POC). Like their four year counterparts, they are paid while at field training and will receive travel pay to and from the Air Force base hosting field training. Students accepted into the Two-Year Program will complete the Professional Officer Course as described above.

OTHER ASPECTS OF THE AFROTC PROGRAM

Leadership Laboratory:
Air Force ROTC officer candidates participate in a Leadership Laboratory (LLAB) where the leadership skills and management theories acquired in the classroom are put into practice. The LLAB meets once each week for approximately two hours.

Field Training:
The summer program is designed to develop military leadership, discipline, and to provide Air Force officer orientation and motivation. At the same time, the Air Force can evaluate each student’s potential as an officer. Field training includes aircraft and aircrew orientation, Air Force professional development orientation, marksmanship training, officer training, physical fitness, and survival training. Uniforms, lodging, and meals are provided at no cost to the cadet, and travel at Air Force expense is authorized by air or privately owned vehicle to and from the individual’s home of record or school. Additionally, after applicable deductions, cadets receive pay of about $500 for the four-week encampment and about $750 for the six week summer camp.

Base Visits:
Air Force ROTC officer candidates have the opportunity to visit Air Force bases for firsthand observation of the operating Air Force. These trips are frequently made on weekends or scheduled to coincide with school vacation periods. Officer candidates may be flown by military aircraft or travel by bus to an Air Force base where they spend several days before returning to campus.

Other Benefits:
The Air Force provides all Air Force ROTC uniforms and textbooks for on-campus programs and field training. All officer candidates who have received an Air Force scholarship or are enrolled in the Professional Officer Course (POC) may travel free on military aircraft on a space available basis.

Additional Information:
In addition to formal activities, the Cadet Wing plans and organizes a full schedule of social events throughout the academic year. These include a Dining-In, Military Ball, a Field Day, and intramural sports activities. Professional Development Training Programs, such as the Rising Sophomore Program, Rising Senior Program and Army Airborne training are also available to selected volunteer officer candidates during the summer.
Arnold Air Society:
Each officer candidate can elect to be part of a national society dedicated to conducting service related events for the Air Force and local community. These Arnold Air Society members are involved in a myriad of service projects to include charity work, service to the poor, work with local orphanages, and similar activities. Twice a year, members participate in conventions/ conclaves held in various cities and attended by members from all the schools in the country sponsoring AFROTC. Membership is by nomination after completion of a one semester, project-oriented pledge program.

Civil Air Patrol:
All Air Force ROTC officer candidates at AFROTC Detachment 340 have the opportunity to become members of the Civil Air Patrol and to receive up to 8 flight orientation rides on Civil Air Patrol aircraft at Worcester Regional Airport.

**BIOLOGY AND BIOTECHNOLOGY**

**E. W. OVERSTRÖM, HEAD**

PROFESSORS: D. S. Adams, J. C. Bagshaw, E. W. Overström, P. J. Weathers

ASSOCIATE PROFESSORS: T. C. Crusberg, S. M. Poltz, J. Rulfs, E. Ryder

ASSISTANT PROFESSORS: D. G. Gibson III, L. Mathews, R. Prusty Rao

ADJUNCT AFFILIATE PROFESSOR: A. Di Iorio

ADJUNCT ASSISTANT PROFESSORS/LAB INSTRUCTORS: M. Buckholt, J. Whitefleet-Smith

**MISSION STATEMENT**
The Department of Biology and Biotechnology will make scholarly scientific and technological advances that will address the changing needs of society. We will prepare well educated scientists able to approach problems with creativity and flexibility. A key element in this preparation is active participation in the process of scientific inquiry.

**PROGRAM EDUCATIONAL OBJECTIVES**
The educational objectives of the Department of Biology and Biotechnology are to prepare students to function as scientists and educators in a broad array of biological disciplines. We recognize that the well educated scientist needs facility in technology and skill in critical thinking to function effectively in the professional arena as well as in the global community.

**PROGRAM OUTCOMES**
Students graduating with a Bachelor of Science degree from the Department of Biology and Biotechnology:

- have mastered a broad range of basic lab skills applicable to biology and biotechnology.
- have mastered applied research skills at an advanced level in at least one area of biology and biotechnology.
- know and understand a broad range of basic biological concepts, and can apply and analyze these in at least one specialty area.
- are able to generate hypotheses, design approaches to test them, and interpret the data from those tests to reach valid conclusions.
- have developed the ability to place their own work in a broader scientific context.
- have developed oral and written communication skills relevant to professional positions in biology and biotechnology.
- can find, read and critically evaluate the original scientific literature.
- possess skills necessary for life-long professional learning.
- can function effectively as members of a team.
- demonstrate adherence to accepted standards of professional and ethical behavior.

**Program Distribution Requirements for the Biology and Biotechnology Major**

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<th>MINIMUM UNITS</th>
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<td>1. Mathematical Sciences, Physics, Computer Science, Engineering (Note 1)</td>
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<td>2. Chemistry</td>
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<td>3. Biology &amp; Biotechnology (Note 2)</td>
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<td>6. MQP</td>
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**NOTES:**
1. BB 3040 may count toward this requirement.
2. Biology & Biotechnology coursework must include 2/3 units at the 1000 level, 4/3 units at the 2000 level, and 4/3 units at the 3000/4000 level, of which at least 1/3 unit must be at the 4000 level. BB 1000, BB 1001 and BB 1002 may not count toward the major requirement. At least 2/3 unit of Biology & Biotechnology coursework must be taken from each of three major divisions of biology (below). The 2/3 unit for each division may include courses from any level (1000-4000).
3. Chosen from BB 2000/3000 Laboratories or CH 4150 and 417X Experimental Biochemistry Laboratories. Must include at least 1/2 unit of course work at the 2000 level.
4. Chosen from the Related Courses List or additional BB 3000/4000 level courses.

**THE THREE MAJOR DIVISIONS OF BIOLOGY**

1. **Cellular and molecular biology**
   - BB 1035 Introduction to Biotechnology
   - BB 2920 Genetics
   - BB 2550 Cell Biology
   - BB 2002 Microbiology
   - BB 3055 Microbial Physiology
   - BB 4008 Cell Culture Theory and Applications
   - BB 4010 Advanced Molecular Genetics
   - BB 4065 Virology
   - BB 4070 Separation of Biological Molecules
   - BB 4550 Advanced Cell Biology
   - BB 4910 Advanced Molecular Biology
   - BB 4955 Recombinant DNA

2. **Biology of the organism**
   - BB 125X Human Biology
   - BB 3101 Anatomy and Physiology I
   - BB 3102 Anatomy and Physiology II
   - BB 3080 Neurobiology
   - BB 3170 Plant Morphology and Development
   - BB 3120 Plant Physiology and Cell Culture
   - BB 3620 Developmental Biology I
   - BB 363X Developmental Biology II
   - BB 3920 Immunology
3. Organisms in their environment
BB 1045  Introduction to Biodiversity
BB 2030  Plant Diversity
BB 2040  Principles of Ecology
BB 3140  Evolution: Pattern and Process
BB 3160  Behavioral Ecology
BB 4160  Population Genetics & Phylogeography
BB 4170  Molecular Ecology

RELATED COURSES
BME 4541  Biological Systems
CE 3059  Environmental Engineering
CH 2330  Organic Chemistry III
CH 3510  Chemical Thermodynamics
CH 4110  Biochemistry I
CH 4120  Biochemistry II
CH 4160  Membrane Biophysics
CH 4190  Regulation of Gene Expression
CHE 3301  Introduction to Biological Engineering

OTHER LABORATORY EXPERIENCE LIST
BME 562  Small Animal Surgery
CE 4060  Environmental Engineering Laboratory
CE 4061  Hydrology
CH 4150  Experimental Biochemistry
GE 2341  Geology

UNDERGRADUATE RESEARCH PROJECTS
The biology and biotechnology facilities offer an exceptional learning opportunity since research in an active laboratory group is the principal teaching tool. Tools for modern biochemistry, molecular biology, tissue culture, fermentation, ecology, microscopy and computer integration are all available to undergraduates.

In conjunction with the faculty, students who wish to expand their educational opportunities pursue many off-campus projects each year. Investigations may take place at institutions that have traditionally worked with WPI, such as the University of Massachusetts Medical School, the Worcester Biotechnology Research Park, Tufts University School of Veterinary Medicine, and the Woods Hole Marine Biological Laboratories. The department also has established links with several companies that provide opportunities for project work and summer employment in applied biology and biotechnology.

Undergraduate research projects may be proposed by individual students or groups of students, or may be selected from ongoing research activities of the faculty. The departmental faculty must be consulted for approval of a project before student work begins.

BIOMEDICAL ENGINEERING

Y. MENDELSON, INTERIM HEAD
ASSOCIATE PROFESSOR: Y. Mendelson, G. D. Pins
ASSISTANT PROFESSORS: K. L. Billiar, G.R. Gaudette, M. Rolle

MISSION STATEMENT
The Biomedical Engineering Department prepares students for rewarding careers in the health care industry or professional programs in biomedical research or medicine.

PROGRAM EDUCATIONAL OBJECTIVES
The educational objectives of the Biomedical Engineering Department are to prepare professionals who possess fundamental knowledge of engineering and basic science and can apply these principles to solve problems in biology and medicine. Through a project-oriented curriculum, which closely embraces the WPI educational philosophy, we prepare students to engage in a lifetime of professionalism and learning.

PROGRAM OUTCOMES
The Biomedical Engineering Department has established 13 educational outcomes in support of our department objectives. These general and specific program criteria indicated below in parentheses meet the requirements for Biomedical Engineering accreditation by ABET (the Accreditation Board for Engineering and Technology). Accordingly, students graduating from the Biomedical Engineering Department will demonstrate:

1. An ability to apply knowledge of advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology (general criterion 3a and program criteria).
2. An ability to design and conduct experiments, as well as to analyze and interpret data from living and non-living systems (general criterion 3b and program criteria).
3. An ability to design a system, component, or process to meet desired needs (general criterion 3c).
4. An ability to function on multi-disciplinary teams (general criterion 3d).
5. An ability to identify, formulate, and solve engineering problems (general criterion 3e).
6. An understanding of professional and ethical responsibilities (general criterion 3f).
7. An ability to communicate effectively (general criterion 3g).
8. The broad education necessary to understand the impact of engineering solutions in a global and societal context (general criterion 3h).
9. A recognition of the need for, and an ability to engage in life-long learning (general criterion 3i).
10. A knowledge of contemporary issues (general criterion 3j).
11. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (general criterion 3k).

12. An understanding of biology and physiology (program criteria).

13. An ability to address the problems associated with the interaction between living and non-living materials and systems (program criteria).

Biomedical engineering is the application of engineering principles to the solution of problems in biology and medicine for the enhancement of health care. Students choose this field in order:

• to be of service to people;

• to work with living systems; and

• to apply advanced technology to solve complex problems of medicine.

Biomedical engineers may be called upon to design instruments and devices, to integrate knowledge from many sources in order to develop new procedures, or to pursue research in order to acquire knowledge needed to solve problems. The major culminates in a Major Qualifying Project, which requires that each student apply his or her engineering background to a suitable biomedical problem, generally in association with the University of Massachusetts Medical School, Tufts University School of Veterinary Medicine, one of the local hospitals, or a medical device company.

Each student's program will be developed individually with an advisor to follow the Biomedical Engineering program chart. WPI requirements applicable to all students must also be met. See page 9.

Biomedical engineering is characterized by the following types of activity in the field:

1. Uncovering new knowledge in areas of biological science and medical practice by applying engineering methods;

2. Studying and solving medical and biological problems through analytical techniques in engineering;

3. Designing and developing patient-related instrumentation, biosensors, prostheses, biocompatible materials, and diagnostic and therapeutic devices; and bioengineered tissues and organs;

4. Analyzing, designing, and implementing improved healthcare delivery systems and apparatus in order to improve patient care and reduce health-care costs in contexts ranging from individual doctors' offices to advanced clinical diagnostic and therapeutic centers.

The modeling of biological systems is an example of applying engineering analytical techniques to better understand the dynamic function of biological systems. The body has a complex feedback control system with multiple subsystems that interact with each other. The application of modeling, computer simulation, and control theory provides insights into the function of these bodily processes.

Recently, there has been increased emphasis on the application of the biomedical engineering principles embodied in the third and fourth areas listed above. Examples of the third area include:

• designing and developing tissues and organs;

• development of implantable biomaterials;

• design of an implantable power source;

• design of transducers to monitor the heart's performance;

• development of electronic circuitry to control the system;

• bench and field testing of devices in animals;

• application of new technology to patients.

The fourth area involves closer contact with the patient and health-care delivery system. This area is commonly referred to as Clinical Engineering. The engineer in the clinical environment normally has responsibility for the medical instrumentation and equipment including:

• writing procurement specifications in consultation with medical and hospital staff;

• inspecting equipment for safe operation and conformance with specifications;

• training medical personnel in proper use of equipment;

• testing within hospital for electrical safety; and

• adaptation of instrumentation to specific applications.

Biomedical engineering projects are available in WPI's Salisbury and Higgins Laboratories, the Life Sciences and Bioengineering Center at Gateway Park as well as at the affiliated institutions previously listed.

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Program Distribution Requirements for the Biomedical Engineering Major

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9), a biomedical engineer needs a solid background in mathematics, physical and life sciences. The distribution requirements are satisfied as follows:

**BIOMEDICAL ENGINEERING MINIMUM UNITS**

1. Mathematics (See Note 1) 2
2. Basic Science (See Note 2) 2
3. Supplemental Science (See Note 3) 2/3
4. Laboratory experience with living systems (See Note 4) 1/3
5. Biomedical Engineering and Engineering (See Note 5) 4 1/3
6. MQP (See Note 6) 1

**NOTES:**

1. Mathematics must include differential and integral calculus, differential equations and statistics.

2. Two courses from each of the following areas: BB, CH and PH.

3. Two courses from BB, CH or PH.

4. Experimental Physiology (e.g., BB 3511 and BB 3514) or equivalent.

5. Thirteen courses from Biomedical Engineering (BME) or Engineering (CE, CHE, ECE, ES, or ME) as specified in the WPI Catalog "Courses Qualifying for Engineering Department Areas" with the following distribution: (1) seven courses from Biomedical Engineering or Engineering, one of which must be an engineering design course; (2) four courses from Biomedical Engineering or Engineering at the 3000-level or above; (3) two courses in Biomedical Engineering at the 4000-level or above. A minimum of eight of the thirteen courses must be from Biomedical Engineering, not including BME 3110.

6. Must include 1/3 unit Capstone Design Experience.
# Biomedical Engineering Program Chart

<table>
<thead>
<tr>
<th>Freshman/Sophomore</th>
<th>Junior</th>
<th>Senior</th>
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</thead>
</table>
| **Mathematics (6 courses)**<br>MA 1021 (Calculus I)<br>MA 1022 (Calculus II)<br>MA 1023 (Calculus III)<br>MA 1024 (Calculus IV)<br>MA 2051 (Differential Equations)<br>MA 2611 (Statistics)<br>**Biology (2 courses)**<br>BB 2550 (Cell Biology)<br>BB 3102 (Physiology: Transport and Maintenance)<br>**Chemistry (2 courses)**<br>CH 1010 (Molecularity)<br>CH 1020 (Forces and Bonding)<br>**Physics (2 courses)**<br>PH 1110 (Physics I)<br>PH 1120 (Physics II)<br>**Supplemental Science (2 courses)**<br>Pick 2 from BB, CH, or PH<br>(See suggested courses from specialization areas listed below)<br>**Biomedical Engineering (select 3 courses)**<br>BME 1001 (Intro. to Bio. Med. Eng.)<br>BME 2204 (Bioelectric Foundations)<br>BME 2504 (Foundations in Biomechanics)<br>BME 2604 (Foundations in Biol. Transport)<br>**H&A Sufficiency (2 Units)**<br>Social Science<br>Physical Education<br>**Free Electives (2/3 Unit)**<br>**Physical Education (1/3 Unit)**<br>**Physical Education (1/3 Unit)**

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<thead>
<tr>
<th>DEGREE REQUIREMENTS</th>
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<tbody>
<tr>
<td>H&amp;A Sufficiency (2 units)</td>
<td>IQP (1 unit)</td>
<td>MQP (1 unit)</td>
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<tr>
<td>Math/Science (4 units)</td>
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<td></td>
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<tr>
<td>Supplemental Science (2/3 Unit)</td>
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<tr>
<td>Biomedical and other Engineering Topics (13/3 Units)</td>
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<tr>
<td>Living Systems Lab (1/3 Unit)</td>
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<tr>
<td>Social Science (2/3 Units)</td>
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<tr>
<td>Free Electives (2/3 Unit)</td>
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<tr>
<td>Physical Education (1/3 Units)</td>
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</tbody>
</table>

**Note:** The total minimum number of BME courses is eight (8)
BIOMEDICAL ENGINEERING SPECIALIZATIONS

Because BME is such a broad and diverse discipline, it is convenient to subdivide it into a number of different specializations, or tracks. At the undergraduate level, these specializations help to bring focus to course and project planning. At the graduate-level, these specializations are aligned with the research interests of our faculty. Here at WPI, five specializations have been defined: Biomaterials, Biomechanics, Biomedical Imaging, Biomedical Sensors and Instrumentation, and Tissue Engineering. If students are interested in developing an undergraduate program of study in one of these specializations, they should consult the Program of Study in BME sections of the catalog, within their chosen areas of specialization. See the department website for more details.

BIOMATERIALS

Biomaterials is a specialization within biomedical engineering that integrates engineering fundamentals in materials science with principles of cell biology, chemistry and physiology to aid in the design and development of materials used in the production of medical devices. When most people first think of biomaterials, implants such as surgical sutures, artificial hips or pacemakers generally comes to mind, but many other aspects are included in this diverse field of study:

• Biomaterials Design – Identify the physiological and engineering criteria that an implantable biomaterial must meet. Select the proper chemical composition to insure that the biomaterial imparts the desired mechanical properties and evokes the appropriate tissue response for the specified application.

• Mechanics of Biomaterials – Characterize the magnitude and nature of the mechanical properties of biomaterials. Predict and measure how the physical/structural properties of a biomaterial determine its mechanical properties.

• Biomaterials-Tissue Interactions – Examine the molecular, cellular and tissue responses to implanted medical devices. Design biomaterials with properties that induce the desired wound healing and tissue remodeling responses from the body.

Biomaterials research and development has improved our health care in many ways including:

• Design and manufacturing of replacements parts for damaged or diseased tissues and organs (e.g., artificial hip joints, kidney dialysis machines)

• Improved wound healing (e.g., sutures, wound dressings)

• Enhanced performance of medical devices (e.g., contact lenses, pacemakers)

• Correct functional abnormalities (e.g., spinal rods)

• Correct cosmetic problems (e.g., reconstructive mammoplasty, chin augmentation)

• Aid in clinical diagnostics (e.g., probes and catheters)

• Aid in clinical treatments (e.g., cardiac stents, drains and catheters)

• Design biodegradable scaffolds for tissue engineering (e.g., dermal analogs)

Suggested Course Table and Sequence

Supplemental Science (Select two courses)
Select two from the following science courses below:
BB 2901 - Molecular Biology, Microbiology, and Genetics
BB 2902 - Enzymes, Proteins, and Purification
BB 2903 - Anatomy and Physiology
BB 3101 - Human Physiology: Movement and Communication
BB 4008 - Cell Culture Theory and Application
CH 2310 - Organic Chemistry I
CH 4110 - Biochemistry I
CH 4550 - Polymer Chemistry (cat. II)

Engineering (Select nine courses)
Select three fundamental engineering courses, preferred choices include:
ES 2501 - Introduction to Static Systems
ES 2502 - Stress Analysis
ME 2820 - Materials Processing

Select two 3000-level (or higher) engineering courses, preferred choices include:
ES 3001 - Introduction to Thermodynamics
ES 3004 - Fluid Mechanics
ME 3023 - Mechanical Behavior and Modeling properties of Engineering Materials
ME 3501 - Continuum Mechanics
ME 3502 - Advanced Mechanics of Materials
ME 4821 - Chemistry, Properties and Processing of Plastics (cat. II)

Select four 3000- and 4000-level BME courses, preferred choices include:
[Note #1]
BME/ME 4504 - Biomechanics (cat. II)
BME/ME 4606 - Biofluids (cat. II)
BME/ME 4814 - Biomaterials
BME 4828 - Biomaterials-Tissue Interactions
BME/ME 550 - Tissue Engineering (cat. II)
BME 595B - Biomaterials in the Design of Medical Devices

Note #1: At least 2 of the BME courses must be at the 4000-level or above.
Graduate level courses can substitute for 4000-level courses.

BIOMECHANICS

Biomechanics is a specialization within biomedical engineering that involves the application of engineering mechanics to the study of biological tissues and physiological systems. When most people first think of biomechanics the way we move or the strength of bones generally comes to mind but many other aspects are included in this diverse field of study including:

• Dynamics – analysis of human movement including walking, running, and throwing.

• Statics – determination of the magnitude and nature of forces in joints, bones, muscles and implanted prostheses, and characterization of the mechanical properties of the tissues in our bodies.

• Fluid mechanics – analysis flow of blood through arteries and air through the lung.

Biomechanics research has improved our understanding of, among other things:

• Design and manufacturing of medical instruments, devices for disabled persons, artificial replacements, and implants.

• Human performance in the workplace and in athletic competition.

• Normal and pathological human and animal locomotion.
• The mechanical properties of hard and soft tissues.
• Neuromuscular control.
• The connection between blood flow and arteriosclerosis.
• Air flow and lung pathology.
• The effects of mechanical loads on cellular mechanics and physiology.
• Morphogenesis, growth, and healing.
• The mechanics of biomaterials.
• Engineering of living replacement tissue (tissue engineering).

Suggested Course Table and Sequence

<table>
<thead>
<tr>
<th>Supplemental Science (Select two courses)</th>
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<tbody>
<tr>
<td>Select two from the following course below:</td>
</tr>
<tr>
<td>BB 2901 - Molecular Biology, Microbiology, and Genetics</td>
</tr>
<tr>
<td>BB 2902 - Enzymes, Proteins, and Purification</td>
</tr>
<tr>
<td>BB 2903 - Anatomy and Physiology</td>
</tr>
<tr>
<td>BB 3101 - Human Anatomy &amp; Physiology: Movement and Communication</td>
</tr>
<tr>
<td>BB 3102 - Human Anatomy &amp; Physiology: Transport and Maintenance</td>
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<tr>
<td>CH 2310 - Organic Chemistry I</td>
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<tr>
<td>CH 4110 - Biochemistry I</td>
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<tr>
<td>CH 4550 - Polymer Chemistry (Cat. II)</td>
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</table>

<table>
<thead>
<tr>
<th>Engineering (Select nine courses)</th>
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<tbody>
<tr>
<td>Select three fundamental engineering courses, preferred choices include:</td>
</tr>
<tr>
<td>ES 2001 - Introduction to Materials Science [Note #2]</td>
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<tr>
<td>ES 2501 - Introduction to Static Systems</td>
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<tr>
<td>ES 2502 - Stress Analysis [Note #2]</td>
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<tr>
<td>ES 2503 - Introduction to Dynamic Systems</td>
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<tr>
<td>Select two 3000-level (or higher) engineering courses, preferred choices include:</td>
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<tr>
<td>ES 3001 - Introduction to Thermodynamics</td>
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<td>ES 3003 - Heat Transfer</td>
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<tr>
<td>ES 3004 - Fluid Mechanics [Note #3]</td>
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<tr>
<td>ES 3011 - Control Systems</td>
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<tr>
<td>ES 3323 - Advanced Computer Aided Design</td>
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<tr>
<td>ME 3023 - Mechanical Behavior and Modeling properties of Engineering Materials</td>
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<td>ME 3310 - Kinematics of Mechanisms</td>
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<td>ME 3321 - Dynamic Modeling</td>
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<tr>
<td>ME 3501 - Continuum Mechanics (Cat. II) [Note #4]</td>
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<tr>
<td>ME 3502 - Advanced Mechanics of Materials</td>
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<td>ME 3506 - Rehabilitation Engineering</td>
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<td>ME 4512 - Introduction to Finite Element Method</td>
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<tr>
<td>Select four 3000- and 4000-level BME courses, preferred choices include: [Note #1]</td>
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<tr>
<td>BME/ME 3504 - Experimental Biomechanics</td>
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<tr>
<td>BME/ME 4504 - Biomechanics (Cat. II)</td>
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<tr>
<td>BME/ME 4606 - Biofluids</td>
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<tr>
<td>BME/ME 4814 - Biomaterials</td>
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<tr>
<td>BME/ME 552 - Tissue Mechanics (Cat. II)</td>
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<tr>
<td>BME/ME 550 - Tissue Engineering (Cat. II)</td>
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<tr>
<td>BME/ME 554 - Composites with Biomedical and Materials Applications</td>
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</table>

Note #1: At least 2 of the BME courses must be at the 4000-level or above. Graduate level courses can substitute for 4000-level courses.
Note #2: These courses should be completed before taking BME 4814.
Note #3: This course should be completed before taking BME 4606.
Note #4: This course should be completed before taking BME 4504 or BME 552.

**BIOMEDICAL IMAGING**

Biomedical imaging is a broad specialization within biomedical engineering that involves the application of quantitative science and engineering to detect and visualize biological processes. An important sub-area in biomedical imaging is the application of these tools and knowledge to the study of diseases with an ultimate goal of aiding medical intervention. While x-ray imaging is an obvious and familiar example with tremendous diagnostic utility, it represents only a small aspect of this important field. Biomedical imaging:

- Includes the numerous and diverse imaging technologies that nearly cover the electromagnetic spectrum. Examples include x-ray imaging, visible light (optical) imaging, near-infrared imaging, magnetic resonance imaging, and ultrasound imaging. The detected radiation can be either naturally emitted by the body (such as infrared radiation) or re-emitted radiation (as in magnetic resonance imaging). It also includes technologies that produce images following the introduction of a chemical agent into the body, such as nuclear medicine imaging and luminescence-based imaging.

- Involves the development of sophisticated instrumentation to acquire and process images from the body, most often in a non-invasive or minimally-invasive manner. A biomedical engineer is not simply a user of an imaging technology, but an active participant in the development of new technologies.

- Requires an understanding of how energy interacts with biological tissue and how this interaction is used to produce images of diagnostic utility. This understanding is rooted in the disciplines of physics, chemistry, and biology. A biomedical engineer, therefore, must have a strong background in the physical sciences.

- Involves both image acquisition and image processing. Rarely are the signals acquired by the instrumentation immediately interpretable. For example, image processing is used to create two- and three-dimensional images from the acquired “raw” signals and to extract important image features. An example is computed tomography, which converts a series of through-body x-ray images into a cross-sectional image that reveals internal tissue structures. Image processing is grounded in the disciplines of mathematics and computer science.

- Is capable of generating much more than simple anatomic images. For example, newer biomedical imaging technologies are being used to image and quantify blood flow and metabolic activity in normal and diseased tissue. The development of these “functional” imaging technologies has tremendous potential to substantially advance our understanding of biological and disease processes. Because it is often completely non-invasive, biomedical imaging is already revolutionizing the study of brain function in humans.

- Involves all size scales, from sub-cellular to whole body.

- Is an important component of many other disciplines and specializations, including biology and tissue engineering. Without the technical advances in biomedical imaging, we would often be at the mercy of time-consuming and tedious chemical or histological analyses to probe cellular function and microscopic structures. Non-invasive methods also allow biological processes to be studied over time on the same sample.
BIOSENSORS AND BIOINSTRUMENTATION

Modern health care relies heavily on a large array of sophisticated medical instrumentation to diagnose health problems, to monitor patient condition and administer therapeutic treatments, most often in a non-invasive or minimally-invasive manner. During the past decade, computers have become an essential part of modern bioinstrumentation, from the microprocessor in a single-purpose instrument used to do a variety of small tasks to the desk-top microcomputer needed to process the large amount of clinical information acquired from patients.

A biomedical engineer is not simply a user of measurement technology, but an active participant in the development of new diagnostic and therapeutic modalities. Hence, the Biosensors and Bioinstrumentation track of our program focuses on training students to design, test, and use sensors and biomedical instrumentation in humans and animals to further enhance the quality of health care. Emphasis is placed both on understanding the physiological systems involved in the generation of the measured variable or affected by therapeutic equipment as well as the engineering principles of new sensors and advanced measurement devices. This track provides an excellent training experience that prepares students for careers in industry, higher education as well as medical school.

Examples of common biomedical sensors, devices, and instrumentation developed by biomedical engineers and used routinely in medicine include:

- Electrical sensors (electrodes)
- Electrocardiographs (a device that measures the electrical activity of the heart)
- Electroencephalograph (a device that measures the electrical activity of the brain)
- Electromyography (a device that measures the electrical activity of muscles)
- Mechanical respirator
- Cardiac pacemaker
- Defibrillators
- Artificial heart
- Pulse oximeters
- Ultrasonic equipment
- Imaging scanners (nuclear cameras, CAT, MRI)
- Drug infusion and insulin pumps
- Electrosurgical equipment
- Heart-lung machine
- Anesthesia machine
- Kidney dialysis machine
- Specialized equipment used by disabled people (e.g., hearing aids)
- Laser systems for eye surgery

Suggested Course Table and Sequence

Supplemental Science (Select two courses)
CH 1040 - Chemistry IV (Dynamics)
CH 4110 - Biochemistry
PH 1140 - Oscillations and Waves
PH 2501 - Photonics
PH 2601 - Photonics Laboratory

Engineering (Select nine courses)
Select three fundamental engineering courses; preferred choices include:
ECE 2011 - Introduction to Electrical and Computer Engineering
ECE 2111 - Physical Principles of ECE Applications
ECE 2112 - Electromagnetic Fields
ECE 2311 - Continuous-Time Signal and System Analysis
ECE 2312 - Discrete-Time Signal and System Analysis

Select two 3000-level (or higher) engineering courses; preferred choices include:
ECE 3113 - Introduction to RF Circuit Design
ECE 3204 - Microelectronic Circuits II
ME 4922 - Theory and Practice of Laser Instrumentation

Select four 3000- and/or 4000-level BME courses; preferred choices include [Note #1]:
BME 3011 - Bioinstrumentation and Biosensors
BME 4011 - Biomedical Signal Analysis
BME 4201 - Biomedical Imaging
BME 4541 - Biological Systems
BME 581 - Medical Imaging Systems
BME 582 - Principles of In Vivo Nuclear Magnetic Resonance Imaging

Select two 3000-level (or higher) engineering courses; preferred choices include:
ECE 4703 - Real-Time Digital Signal Processing
ECE 3801 - Advanced Logic Design
ECE 2201 - Microelectronic Circuits I
ECE 2312 - Discrete-Time Signal and System Analysis
ECE 2799 - Electrical & Computer Engineering Design

Select four 3000- and/or 4000-level BE courses; preferred choices include [Note #1]:
BME 3011 - Bioinstrumentation and Biosensors
BME 4011 - Biomedical Signal Analysis
BME 4023 - Biomedical Instrumentation I
BME 4025 - Biomedical Instrumentation II
BME 4541 - Biological Systems

Note #1: At least 2 of the BE courses must be at the 4000-level or above. Graduate level courses can substitute for 4000-level courses.
TISSUE ENGINEERING

Tissue engineering integrates the principles and methods of engineering with the fundamentals of life sciences towards the development of biological substitutes to restore, maintain or improve tissue/organ function. When most people first think of tissue engineering, artificial skin and cartilage generally comes to mind, but many other aspects are included in this diverse field of study:

- Scaffold/Biomaterial Design – Identify the physiological and engineering criteria that a biodegradable scaffold must meet. Select the proper biochemical composition to insure that the cells perform in a physiologic manner on the surface of the scaffold.
- Functional/Biomechanical Tissue Engineering – Characterize the roles of biomechanical stimuli on the growth and development of bioengineered cells, tissues and organs. Measure the biomechanical properties of bioengineered tissues and organs.
- Bioreactor Design – Design reactors that control the rates at which nutrients and growth factors are supplied to bioengineered tissues and organs during growth and development in a laboratory environment.

Suggested Course Table and Sequence

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<td>ME 3023 - Mechanical Behavior and Modeling properties of Engineering Materials</td>
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<td>ME 3502 - Advanced Mechanics of Materials</td>
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<tr>
<td>ME 4821 - Chemistry, Properties and Processing of Plastics (cat. II)</td>
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<tr>
<td>Select four 3000- and 4000-level BME courses, preferred choices include:</td>
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<tr>
<td>BME/ME 4606 - Biofluids (cat. II)</td>
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<tr>
<td>BME/ME 4814 - Biomaterials</td>
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<td>BME 595B - Biomaterials in the Design of Medical Devices</td>
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</tbody>
</table>

Note #1: At least 2 of the BME courses must be at the 4000-level or above. Graduate level courses can substitute for 4000-level courses.

CHEMICAL ENGINEERING

D. DIBIASIO, HEAD
PROFESSORS: R. Datta, A. G. Dixon, Y. H. Ma,
R. W. Thompson
ASSOCIATE PROFESSORS: T. A. Camesano, W. M. Clark,
D. DiBiasio, N. K. Kazantzis
ASSISTANT PROFESSOR: H. Zhou
RESEARCH ASSOCIATE PROFESSOR: I. Fishtik
RESEARCH ASSISTANT PROFESSOR: I. Mardilovich
ADJUNCT ASSISTANT PROFESSORS: H. W. Nowick, T. Starr,
S. Kniolek

MISSION STATEMENT

The Department of Chemical Engineering at WPI is dedicated to providing excellent education to undergraduate and graduate students in chemical engineering, and to vigorously pursuing discovery, creation, and dissemination of knowledge at the frontiers of chemical engineering. Chemical engineers are uniquely positioned to continue to contribute to the betterment of society through advancements in new materials, biomedicine, alternative energy, transportation, environmental pollution abatement, resource conservation, and sustainable development.

The Department aspires to contribute to this vision by achieving national distinction in selected areas of scholarly inquiry and by educating men and women to become leaders in industrial practice, civil service, education, and research. The Department strives to produce technically competent and socially aware chemical engineers through project-based, innovative, and rigorous educational programs that promote global and societal awareness, innovative thinking, and life-long learning skills.

PROGRAM EDUCATIONAL OBJECTIVES

The Chemical Engineering Department has established the following objectives of the undergraduate program in support of our mission and that of the Institute.

1. To educate students in the fundamental principles of chemical engineering.
2. To help students develop the ability to use chemical engineering principles to solve problems of practical importance to society.
3. To help prepare students, through broad education, for a lifetime of success as productive and informed members of society as well as of their professional community.
4. To help students become effective communicators.

PROGRAM OUTCOMES

The Chemical Engineering Department has established fifteen educational outcomes in support of our objectives. The outcomes are grouped under the objectives that they support.

Objective 1

1.1 Chemical engineering graduates will possess a working knowledge of the fundamentals of chemistry, physics, and mathematics, including knowledge of advanced elective science subjects such as organic and inorganic chemistry, material science, and biochemistry, etc.
1.2 Chemical engineering graduates will possess a working knowledge of conservation principles and their applications, physical and chemical equilibria, transport and rate processes, separation processes, chemical process control, and reaction engineering.

Objective 2

2.1 Chemical engineering graduates will be able to formulate, analyze, and solve practical chemical engineering problems.

2.2 Chemical engineering graduates will be able to design experiments, safely gather and analyze data, and apply the results to address practical chemical engineering problems.

2.3 Chemical engineering graduates will be able to use appropriate mathematical concepts and methods to solve chemical engineering problems.

2.4 Chemical engineering graduates will be able to design a chemical system, process, or component with consideration of realistic constraints including practical, economic, environmental, safety, ethical, social, and political implications.

2.5 Chemical engineering graduates will be able to use computers effectively for solving chemical engineering problems.

Objective 3

3.1 Chemical engineering graduates will be able to function and work effectively alone and in a team environment, including multidisciplinary teams.

3.2 Chemical engineering graduates will possess an appreciation of professional, ethical, and contemporary issues, and the societal and global impact of chemical engineering processes.

3.3 Chemical engineering graduates will possess self-learning skills to ensure life-long learning.

3.4 Chemical engineering graduates will possess an appreciation for the humanities and social sciences.

3.5 Chemical engineering graduates will be able to use their chemical engineering education to serve the chemical engineering profession or a related profession or pursue advanced studies.

3.6 Chemical engineering graduates will have selected technical elective courses, concentrations, projects, and minors that satisfy their professional interest or career goals.

Objective 4

4.1 Chemical engineering graduates will be able to write coherent, concise, and accurate technical reports.

4.2 Chemical engineering graduates will be able to make concise and effective oral presentations.

Program Distribution Requirements for the Chemical Engineering Major

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9), students wishing to receive the ABET-accredited degree designated “Chemical Engineering” must satisfy the distribution requirements shown below.

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
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<tbody>
<tr>
<td>1. Mathematics and Base Science (Notes 1 and 2)</td>
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<tr>
<td>2. Engineering Science and Design (Notes 3 and 4)</td>
<td>6</td>
</tr>
<tr>
<td>3. Advanced Chemistry and Natural Science (Note 5)</td>
<td>5/3</td>
</tr>
</tbody>
</table>

NOTES:

1. Must include differential and integral calculus and differential equations.
2. Must include 3 courses in chemistry, 2 courses in physics and 1 course in biology or biochemistry.
3. Must include at least 1/3 unit of capstone design experience (e.g. CHE 4404) and at least 1/3 unit of engineering study outside the major. Courses used to satisfy this requirement must be at the 2000 level or above, with the exception of CHE 1011.
4. Must include at least 4 units from the following list of core chemical engineering courses: CHE 2011, CHE 2011, CHE 2013, CHE 2014, ES 3004, ES 3003, ES 3002, CHE 3201, CHE 3501, CHE 4401, CHE 4402, CHE 4403, CHE 4404, CHE 4405.
5. Advanced chemistry and natural science courses are defined as any 2000 level and above BB, CH, PH, or GE course and CH 1040. Must include 3 advanced CH courses at 2000 level or above. Up to 2/3 unit of advanced chemistry and natural science may be double counted under requirements 1 and 3.

CONCENTRATIONS FOR CHEMICAL ENGINEERING MAJORS

Chemical engineering majors may choose to focus their studies by obtaining one of the following Concentrations: Biochemical, Biomedical, Environmental, or Materials.

CHEMICAL ENGINEERING WITH BIOCHEMICAL CONCENTRATION

Basic Science:
Any BB course. No more than one 1000 level course may be counted, however. Recommended courses include:

- BB 2002 Microbiology
- BB 3055 Microbial Physiology
- BB 4008 Cell Culture Theory and Applications
- BB 4070 Separation of Biological Molecules
- BB 560 Separation of Biological Molecules

Engineering Science and Design:

- BB 509 Scale-Up of Bioprocessing
- CHE 3301 Introduction to Biological Engineering
- CHE 521 Biochemical Engineering
- BME 1001 Introduction to Biomedical Engineering

Advanced Chemistry:

- CH 4110 Biochemistry I
- CH 4120 Biochemistry II
- CH 4130 Biochemistry III
- BB 4910 Advanced Molecular Biology
CHEMICAL ENGINEERING WITH BIOMEDICAL CONCENTRATION
No more than one 1000-level course may be counted. Recommended courses include:

**Basic Science:**
(at most, one of these three)
- BB 1035 Introduction to Biotechnology
- BB 2550 Cell Biology
- BB 125X Human Biology
- BB 3102 Human Anatomy & Physiology: Transport and Maintenance
- BB 4065 Virology

**Engineering Science and Design:**
- BME 1001 Introduction to Biomedical Engineering
- BME 2604 Foundations in Biological Transport Phenomena
- BME/ME 4504 Biomechanics
- BME/ME 4606 Biofluids
- BME/ME 4814 Biomaterials
- CHE 3301 Introduction to Biological Engineering

CHEMICAL ENGINEERING WITH ENVIRONMENTAL CONCENTRATION

**Basic Science:**
- GE 2341 Geology
- BB 2040 Principles of Ecology

**Engineering Science and Design:**
(at most, one of these three)
- CHE 3301 Introduction to Biological Engineering
- CHE 3910 Chemical and Environmental Technology
- CHE 3920 Air Quality Management
- CE 3059 Environmental Engineering
- CE 3070 Introduction to Urban and Environmental Planning
- CE 3074 Environmental Analysis
- CE 3060 Water Treatment
- CE 3061 Wastewater Treatment
- CE 4060 Environmental Engineering Lab
- CE 4061 Hydrology

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**CHEMICAL ENGINEERING SUGGESTED COURSE SEQUENCE**

```
CHE 1011
CHE 2011
CHE 2012
CHE 2013
CHE 2014
ES 3004
ES 3003
ES 3002
CHE 3301
CHE 3201
CHE 3501
CHE 3601
CHE 3910
CHE 3920
CHE 4401
CHE 4403
CHE 4401
CHE 4402
CHE 4404
CHE 4405
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MAIN SEQUENCE
ELECTIVES
CHEMICAL ENGINEERING WITH MATERIALS CONCENTRATION

Engineering Science and Design:
CHE 3601 Chemical Materials Engineering
ES 2001 Introduction to Material Science
CHE 508 Catalysis and Surface Science of Materials
ME 2820 Materials Processing
ME 3801 Experimental Methods in Material Science and Engineering
ME 4813 Ceramics
ME 4814 Biomaterials
ME 4821 Chemistry, Properties, and Processing of Plastics
ME 4840 Physical Metallurgy
ME 48xx (Materials courses as approved)

Advanced Chemistry:
CH 4550 Polymer Chemistry

PROJECT OPPORTUNITIES
Projects available to the chemical engineering student are of the widest possible variety. Projects may be of the research type (as would be encountered in graduate school) or of a more developmental, industrial nature. Nonexperimental design projects or theoretical projects are also available. They are available on campus, sometimes with graduate students working on sponsored research; in off-campus governmental laboratories; or in industry, as well as overseas.

Areas of specialization in the department currently are:
Adorption Kinetics
Biochemical Engineering Mass Transfer
Biofilms Materials Synthesis
Biominiaturization Microfluidics
Bioremediation Molecular Modeling
Biosensors Process Dynamics, Supervision and Control
Biotechnology Catalysis Reaction Engineering
Diffusion Scientific Computing
Drug Delivery Separation Processes
Fuel Cells Thermodynamics
Hydrogen Technology Water Remediation
Inorganic Membranes Zeolites

CHEMISTRY AND BIOCHEMISTRY

K. N. WOBBE, INTERIM HEAD
ASSOCIATE PROFESSORS: J.C. MacDonald, K.N. Wobbe
ASSISTANT PROFESSORS: V. Thalladli, W. Yu

MISSION STATEMENT
Through dynamic and innovative classroom instruction and exciting cutting edge research programs, the Department of Chemistry and Biochemistry strives to provide students with both a broad understanding of the fundamentals of the chemical sciences and an opportunity to create new chemical and biochemical knowledge through original research. We aspire to produce graduates who will enter their scientific careers with the confidence and competence to lead the advance of chemistry and biochemistry in the 21st century.

PROGRAM EDUCATIONAL OBJECTIVES
The Department of Chemistry and Biochemistry will graduate outstanding professionals possessing fundamental knowledge of the chemical sciences. Graduates will be able to apply this knowledge to the solution of problems in chemistry and biochemistry for the advancement of knowledge in these fields and the improvement of the standard of living of all humanity.

PROGRAM OUTCOMES
Students graduating with a major in Chemistry or Biochemistry will be able to demonstrate an ability to
• perform accurate and precise quantitative measurements
• use and understand modern instruments, particularly NMR, IR, and UV-vis spectrometers, chromatographs, electrochemical instruments, and lab computers
• keep legible and complete experimental records
• analyze data statistically and assess reliability of results
• anticipate, recognize, and respond properly to hazards of chemical manipulations
• interpret experimental results and draw reasonable conclusions
• plan and execute experiments through use of the literature
• design experiments
• communicate effectively through oral and written reports
• critically assess their work for reasonableness and self-consistency
• adhere to high ethical standards
• learn independently

BIOCHEMISTRY

Program Distribution Requirements for the Biochemistry Major

In addition to the WPI requirements applicable to all students (see page 9), students wishing to graduate with a degree in biochemistry must meet the distribution requirements detailed below.

REQUIREMENTS MINIMUM UNITS
1. Mathematics and Physics (Note 1). 2
2. Chemistry and Biochemistry (Note 2). 4
3. Biology (Note 3). 1 2/3
4. Chemistry and Biochemistry/Biology Laboratory (Note 4). 1
5. Other Natural or Computer Science (Note 5). 1/3
6. MQP 1

NOTES:
1. The mathematics in MA 1021-MA 1024 or the equivalent is recommended. The physics in PH 1110-PH 1120 or equivalent is recommended.
2. These four units must include one unit of organic, one unit of biochemistry, and 1/3 unit each of physical (3000 level or higher) and inorganic chemistry (5000 level or higher).
3. These 1 2/3 units must include 1/3 unit of cell biology, 1/3 unit of genetics, and 2/3 unit of advanced work (3000 level or higher).
4. This unit must include a minimum of 1/3 unit in Chemistry and Biochemistry, and a minimum of 1/3 unit in Biology.
5. Any course in the natural sciences (not used to satisfy another requirement) or in computer science may be used to satisfy this requirement.
RECOMMENDATIONS FOR STUDENTS

A typical Biochemistry curriculum is given below.

Premedical students should take three terms of Physics, as well as one of the Organic Chemistry Laboratories (CH 2360 or CH 2660), by the end of their third year.

BB 1035 is recommended as the initial course for students who need to strengthen their background in biology. Note that a total of one unit designated Elective in the table must be in Biology.

Students should take 1/3 unit of advanced Biology laboratory (BB 3512, 3518, 3519, 3520 are recommended) at their discretion as to the term; however, this should preferably be done before the MQP is commenced.

Recommended Biochemistry Program

<table>
<thead>
<tr>
<th>Year</th>
<th>Term A</th>
<th>Term B</th>
<th>Term C</th>
<th>Term D</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>CH 1010 BB 2550</td>
<td>CH 1020 HU MA</td>
<td>CH 1030 BB 2920 MA</td>
<td>CH 1040 HU MA</td>
</tr>
<tr>
<td>Second</td>
<td>CH 3510 CH 2640</td>
<td>CH 2310 HU SS HU</td>
<td>CH 2320 HU PH</td>
<td>CH 2330 HU PH</td>
</tr>
<tr>
<td>Third</td>
<td>CH 4110 BB Lab SS</td>
<td>CH 4120 CH 4150 IQP</td>
<td>CH 4130 CH 3410 IQP</td>
<td>CH 4170 Elective IQP</td>
</tr>
<tr>
<td>Fourth</td>
<td>Elective MQP Elective</td>
<td>Elective MQP Elective</td>
<td>Elective 4160 MQP Elective</td>
<td>Elective 4190 MQP Elective</td>
</tr>
</tbody>
</table>

ASSOCIATED BIOCHEMISTRY FACULTY


CHEMISTRY

Program Distribution Requirements for the Chemistry Major

In addition to the WPI requirements applicable to all students (see page 9), students wishing to graduate with a degree in chemistry must meet the distribution requirements detailed below.

REQUIREMENTS

1. Mathematics and Physics (Note 1). 2 1/3
2. Chemistry (Note 2). 4
3. Additional Science/Engineering (Note 3). 3 2/3

NOTES:

1. Must include differential and integral calculus and at least 2/3 units of physics.
2. Must be above the level of general chemistry (2000 level or higher). These 4 units must include courses in experimental chemistry (either 4/3 unit or 3/3 unit), inorganic chemistry (1/3 unit), organic chemistry (3/3 unit), physical chemistry (3/3 unit), and biochemistry (either 1/3 unit or 2/3 unit, depending on the number of experimental chemistry courses taken). At least 2/3 units must be at or higher than the 4000 level.
3. Distributed among the MQP, the natural and physical sciences, computer science, mathematics, and engineering (and including general chemistry, CH 1010-1040).

RECOMMENDATIONS FOR STUDENTS

Chemistry utilizes many of the concepts of physics and the tools of mathematics. Thus students should acquire a background in these subjects early in their programs. The material addressed in MA 1021 through MA 1024 is recommended for all chemistry majors. Students will also benefit from knowledge of differential equations, as discussed in MA 2051. Physics background should include mechanics, and electricity and magnetism. Either the PH 1110-1120 or the PH 1111-1121 sequence is recommended. Students seeking more depth in physics are advised to pursue PH 1130 and PH 1140.

Students seeking ACS certification (see below) should plan to study calculus through introductory multivariable calculus (MA 1021-1024), differential equations (MA 2051) and linear algebra (MA 2071), and should take a minimum of two courses in physics (for example, PH 1111 and PH 1121).

AMERICAN CHEMICAL SOCIETY APPROVAL AND CERTIFICATION

The Department of Chemistry and Biochemistry has an American Chemical Society (ACS) approved program. Thus graduates who complete programs satisfying the ACS recommendations have their degrees certified to the society by the department. Accordingly, students can earn an “ACS-Certified Degree in Chemistry” or an “ACS-Certified Degree in Chemistry with a Biochemistry Option.”

ACS-Certified graduates are eligible for immediate membership in the ACS and thus are able to secure the benefits of membership, which include helpful services such as finding employment.

ACS-CERTIFIED DEGREE IN CHEMISTRY

The following sequence of courses, recommended to provide fundamental background in chemistry, will result in an ACS-certified degree in chemistry. Specialization in particular areas of interest is best accomplished via additional courses and projects, generally taken in the third and fourth years.

Recommended CBC Courses for an ACS-Certified Degree in Chemistry

<table>
<thead>
<tr>
<th>Year</th>
<th>Term A</th>
<th>Term B</th>
<th>Term C</th>
<th>Term D</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>CH 1010</td>
<td>CH 1020</td>
<td>CH 1030</td>
<td>CH 1040</td>
</tr>
<tr>
<td>Second</td>
<td>CH 2640 (lab)</td>
<td>CH 2650 (lab)</td>
<td>CH 2660 (lab)</td>
<td>CH 2670 (lab)</td>
</tr>
<tr>
<td>Third</td>
<td>CH 3510 (phys)</td>
<td>CH 3550 (phys)</td>
<td>CH 3410 (nong)</td>
<td>CH 3530 (phys)</td>
</tr>
<tr>
<td>Fourth</td>
<td>CH 4110 (bioch)</td>
<td>CH 4420 (nong)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ACS-CERTIFIED DEGREE IN CHEMISTRY WITH A BIOCHEMISTRY OPTION

Students seeking the ACS-Certified Degree with Biochemistry Option must complete the following work in addition to those requirements noted above for an ACS-Certified Degree in Chemistry.

• 1/3 unit of biology which contains cell biology, microbiology or genetics.
• 2/3 unit of biochemistry that has organic chemistry as a prerequisite.
• 1/3 unit of a laboratory in biochemical methods.
• Research in biochemistry culminating in a comprehensive written report is highly recommended.
CONCENTRATION IN MEDICINAL CHEMISTRY

Medicinal Chemistry is the application of principles of biology and chemistry to the rational design and synthesis of new drugs for treatment of disease. A medicinal chemist applies knowledge of chemistry, biochemistry and physiology to generate solutions to health-related problems.

A concentration in medicinal chemistry is excellent preparation for students interested in entering health related professions, such as the pharmaceutical industry, upon graduation. Possible employment positions are numerous and expected to increase in the future.

COURSE REQUIREMENTS
In order to be eligible to receive the Medicinal Chemistry designation on their transcripts, chemistry majors need to satisfy the following course requirements:

- Three biomedically oriented courses selected from the following list must be included in the distribution requirements:
  - CH 4110 Biochemistry I
  - CH 4120 Biochemistry II
  - CH 4130 Biochemistry III
  - BB 4910 Advanced Molecular Biology
  - BB 4955 Recombinant DNA Principles and Applications

  Three courses oriented toward structure, synthesis, or mechanisms selected from the following list must be included in the distribution requirements. (All graduate courses in chemistry are open to undergraduates.)
  - CH 4330 Organic Synthesis
  - CH 516 Chemical Spectroscopy
  - CH 533 Physical Organic Chemistry
  - CH 538 Medicinal Chemistry
  - CH 554 Molecular Modeling

  In addition to the above course requirements, chemistry majors must complete an MQP in the medicinal chemistry area, approved by the Program Coordinator. Examples of available projects are:
  - Synthesis of opiate analogs.
  - Synthesis and testing of compounds that influence transport properties of biological membranes.

PROJECT ACTIVITY
A student undertaking a Major Qualifying Project in chemistry and biochemistry chooses a faculty advisor in the department with whom to work. This choice is normally made because the student is interested in the research program directed by the faculty member, and wants to become a part of this activity. The student is given a research problem to work on for a minimum of 20 hours a week for 3 terms. Although most MQP projects in chemistry and biochemistry are individual student efforts, team projects involving up to 3 students are occasionally available, depending on the faculty member concerned. The project culminates in a formal written MQP report and a poster session presentation to the department faculty and students. MQP projects in chemistry and biochemistry require a substantial effort from the student in both the laboratory and writing phases. Many projects result in professional publications and/or presentations at professional meetings. The department offers a variety of areas of specialization in chemistry and biochemistry below) in which Major Qualifying Projects may be carried out.

Some students, particularly those in biochemistry, choose to do their MQPs at off-campus laboratories. Biochemistry projects have recently been completed at the University of Massachusetts Medical Center and Tufts University School of Veterinary Medicine.

AREAS OF SPECIALIZATION IN CHEMISTRY AND BIOCHEMISTRY

- Computational Chemistry and Molecular Modeling
- Gene Regulation
- Ion Transport
- Materials
- Medicinal Chemistry
- Membrane Proteins
- Molecular Spectroscopy
- Nanoscale Design
- Natural Products Synthesis
- Plant-Virus Biochemistry
- Photochemistry
- Photophysics
- Sensors
- Supramolecular Chemistry

CIVIL AND ENVIRONMENTAL ENGINEERING

T. El-Korchi, Interim Head
PROFESSORS: T. El-Korchi, F. L. Hart, J. C. O’Shaughnessy
ASSISTANT PROFESSOR: M. Tao
ADJUNCT FACULTY: J. Hall, L. Malloy
EMERITUS PROFESSORS: F. DeFalco, R. Fitzgerald

MISSION STATEMENT
The Civil Engineering program at WPI prepares graduates for careers in civil engineering, emphasizing professional practice, civic contributions, and leadership, sustained by active life-long learning. The curriculum combines project based learning environment with a broad background in the fundamental principles of civil engineering. Students have the flexibility to explore various civil engineering disciplines and career opportunities.

PROGRAM EDUCATIONAL OBJECTIVES

1. A graduate should be able to apply the fundamental principles of mathematics, science, and civil engineering to analyze and design a component, process or system.
2. A graduate should have the interpersonal and communication skills, an understanding of ethical responsibility, and a professional attitude necessary for a successful engineering career.
3. A graduate should have the ability to engage in life-long learning.
4. A graduate should have an appreciation for the interrelationships among basic knowledge, technology, and society.
PROGRAM OUTCOMES

1. Preparation for engineering practice, including the technical, professional, and ethical components.
2. Preparation for the future changes in civil engineering.
3. A solid understanding of the basic principles of civil engineering
4. An understanding of appropriate scientific concepts, and an ability to apply them to civil engineering.
5. An understanding of the engineering design process and an ability to perform engineering design, which includes the multidisciplinary aspects of the engineering design process, the need for collaboration and communications skills, plus the importance of cost and time management.
6. Demonstration of an ability to set up experiments, gather and analyze data, and apply the data to practical engineering problems.
7. Demonstration of an ability to set up experiments, gather and analyze data, and apply the data to practical engineering problems.
8. Understanding of options for careers and further education, and the educational preparation necessary to pursue those options.
9. An ability to learn independently.
10. The broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI.
11. An understanding of civil engineering profession in a societal and global context.

Program Distribution Requirements for the Civil Engineering Major

The normal period of undergraduate residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9), students wishing to receive the ABET-accredited degree designated "Civil Engineering" must satisfy certain distribution units of study in the areas of mathematics, basic science, and engineering science and design as follows:

REQUIREMENTS  
MINIMUM UNITS
1. Mathematics and Basic Science (Notes 1,2).  
2. Engineering Science and Design  
(including the MQP) (Note 3,4,5,6).*  

NOTES:
1. Mathematics must include differential and integral calculus, differential equations, and probability and statistics.
2. Must include both chemistry and physics with a minimum of one course in physics and two courses in chemistry.
3. A minimum of 4 units of work must be within the Civil Engineering area. All CE courses including the MQP, ES 2503, and ES 3004 are acceptable within the Civil Engineering area.
4. The curriculum must include at least one engineering science course outside the major discipline area. Courses acceptable to satisfy the requirement of outside-of-discipline course are taught in other engineering departments. The course must be 2000-level or above and cannot include ES 2501, ES 2502, ES 2503, and ES 3004.
5. All students are required to include an appropriate laboratory experience as part of their overall program. This experience can be met by the completion of two undergraduate CE lab courses, selected from among the following: CE 2020, CE 3024, CE 3026, CE 4046, CE 4054, and CE 4060. Alternately, an appropriate laboratory experience could also be accomplished by a student through careful planning of course, project and laboratory work and approval by petition through the Department Program Review Committee.
6. Must include 1/3 unit of Capstone Design Experience.

SUBAREAS OF CIVIL ENGINEERING

STRUCTURAL AND GEOTECHNICAL ENGINEERING

The practice of structural engineering involves the analysis and design of buildings, bridges and other structures which are generally a part of all civil engineering systems. Geotechnical engineering encompasses a broad spectrum of interests including the design, analysis and construction of foundations for buildings and other structures, highway embankments, dams and waste containment facilities. It also considers tunnels, ground water development and engineering in the ocean environment.

An educational program leading to preparation for a career in structural and geotechnical engineering must necessarily include in-depth studies in the basic sciences, mechanics of materials, structural analysis, and design, computer applications, and engineering properties of construction materials. The important courses in this area are CE 2002, CE 3006, CE 3008, CE 3010, CE 3026, CE 3044, CE 4007 and CE 4046. Structures generally are a part of large engineering projects and systems. A valuable component of an engineering education involves the interface with other engineering areas. Knowledge of subject matter contained in CE 3020, CE 3050, CE 3059 and CE 3070 is useful for the structural or geotechnical engineer. Major Qualifying Projects in this field often focus primarily on either structural or geotechnical aspects, although many projects integrate the two areas, in addition to construction project management. Representative recent MQP topics include comparative building design and integration of design and construction.

ENVIRONMENTAL ENGINEERING

Environmental engineering is that branch of civil engineering involved with environmental quality control. The practicing environmental engineer is concerned with planning, design, construction, operation and regulation of water quality control systems related to water supply and treatment, and waste water collection and treatment. The environmental engineer is also concerned with solid waste management, public health, radiological health, and air pollution control. The Civil Engineering Department at WPI emphasizes water quality aspects of environmental engineering. Key courses of this subarea are CE 3004, CE 3059, CE 3060, CE 3061, CE 3062, and CE 3074. Further depth in this field can be obtained by taking CE 4060, CE 4061 and other appropriate courses in chemistry, biology and biotechnology, chemical engineering, and fluid mechanics. The student should attempt to obtain some social science background, particularly in economics and possibly in law. Other engineering areas will enhance the environmental component of large projects. Courses such as CE 3010, CE 3020, CE 3050 and CE 3070 will be helpful. Recent MQP topics have focused on multimedia contaminant transport, pollution prevention, water quality issues, biosolids, and environmental impact.

TRANSPORTATION ENGINEERING

Transportation engineering is concerned with finding solutions to transportation problems such as designing and constructing safe, stable and durable pavement to carry large volumes of traffic vehicles that will be used in the 21st century. The highway infrastructure system in the US plays an important role
STUDENTS EARNING AN ABET ACCREDITED DEGREE IN CIVIL ENGINEERING MUST COMPLETE A MINIMUM OF 15 UNITS OF STUDY ARRANGED IN ACCORDANCE WITH THE DISTRIBUTION REQUIREMENTS. THIS CHART SUMMARIZES COURSE RECOMMENDATIONS--SEE YOUR ADVISOR TO DEVELOP YOUR PROGRAM SCHEDULE.

<table>
<thead>
<tr>
<th>MATHEMATICS</th>
<th>SCIENCE †</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Units Required</td>
<td></td>
</tr>
<tr>
<td>MA1020/1021*</td>
<td>CH 1010</td>
</tr>
<tr>
<td>MA 1022*</td>
<td>CH 1020</td>
</tr>
<tr>
<td>MA 1023*</td>
<td>CH 1030</td>
</tr>
<tr>
<td>MA 1024</td>
<td>PH 1110</td>
</tr>
<tr>
<td>MA 2051*</td>
<td>PH 1120</td>
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<td>MA 2071</td>
<td>PH 1130</td>
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<tr>
<td>MA 2210</td>
<td>BB 1001</td>
</tr>
<tr>
<td>MA 2611*</td>
<td>GE 2341</td>
</tr>
</tbody>
</table>

NOTES
- Basic math and science courses should be completed early in the curriculum, prior to taking many CE courses. Students may select from other math and science courses in addition to those listed here.

* Mathematics requirements include differential and integral calculus, differential equations, and probability and statistics.

† Science: Must include both chemistry and physics with a minimum of one course in physics and two courses in chemistry.

### ENGINEERING SCIENCE AND DESIGN

6 Units Minimum Required
(Minimum 4 Units in the Civil Engineering area as noted in Distribution Requirements)

<table>
<thead>
<tr>
<th>Fundamental Courses</th>
<th>Background Courses</th>
</tr>
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<tbody>
<tr>
<td>CE 1030 (1), CE 2000 (1), CE 2001 (1), CE 2020 (3), ES 3004 (1), CE 3041</td>
<td>CE 3030, ES 2503 (1), ES 3001 (1,2), ECE 3601 (1,2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area (4,5)</th>
<th>Structural</th>
<th>Geotechnical</th>
<th>Environmental and Hydraulics</th>
<th>Urban and Environmental Planning</th>
<th>Transportation</th>
<th>Construction and Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadth</td>
<td>CE 3010</td>
<td>CE 3041</td>
<td>CE 3059</td>
<td>CE 3070</td>
<td>CE 3050</td>
<td>CE 3020 (1)</td>
</tr>
<tr>
<td>Depth</td>
<td>CE 2002</td>
<td>CE 4044</td>
<td>CE 3060</td>
<td>CE 3074</td>
<td>CE 3051</td>
<td>CE 3021</td>
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<td>CE 3006</td>
<td>CE 4046 (3)</td>
<td>CE 3061</td>
<td>CE 4071</td>
<td>CE 4054 (3)</td>
<td>CE 3022 (1)</td>
</tr>
<tr>
<td></td>
<td>CE 3008</td>
<td>CE 4048</td>
<td>CE 3062</td>
<td></td>
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<td>CE 3026 (3)</td>
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<td></td>
<td>CE 4007</td>
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<td>CE 4061</td>
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<td>CE 4017</td>
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</table>

<table>
<thead>
<tr>
<th>MQP</th>
<th>1 Unit Emphasizing Design (in area of choice)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Should be completed in senior year and meet capstone design requirement.</td>
</tr>
</tbody>
</table>

NOTES
1. Includes material covered on Fundamentals of Engineering General Exam.
2. Meets the requirement for at least one engineering science course outside of Civil Engineering.
3. Meets the requirement for appropriate laboratory experience (two laboratory courses required).
4. To demonstrate breadth, students must select courses from a minimum of four areas. Courses should also be selected to demonstrate depth in at least one area.
5. Many areas are interrelated. See your advisor for information on depth courses that are related to your area of interest.

### ADDITIONAL DEGREE REQUIREMENTS

4 UNITS REQUIRED

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Science</td>
<td>2/3 Units</td>
</tr>
<tr>
<td>Humanities and Arts</td>
<td>2 Units (includes Sufficiency)</td>
</tr>
<tr>
<td>IQP</td>
<td>1 Unit</td>
</tr>
<tr>
<td>Physical Education</td>
<td>1/3 Unit</td>
</tr>
</tbody>
</table>
in the commerce, economic development and security of the nation. These systems are deteriorating at a fast pace because of age, heavy increase in use and loading and deferred maintenance. While the highway infrastructure systems need to be enhanced and maintained in order to provide the mobility needs of the nation, improvements must also be safe, efficient and environmentally benign.

A comprehensive set of courses is offered for providing both basic and in-depth knowledge in transportation engineering. The principal emphasis of transportation engineering at WPI is on traffic engineering, highway design, highway and roadside safety, principles of drainage and construction materials and pavement management. Students can gain basic understanding from breadth courses and in-depth knowledge about specific topics by taking depth courses. Breadth courses in this area are CE 3050 and CE 3026. Depth courses are CE 3051, and CE 4054.

The transportation engineering sub-area offers a wide range of MQP topics, which involve practical application of design principles in solving real-world problems. Recent MQP topics include structural design of airport pavements, use of non-destructive testing in pavement design and evaluation, design of durable asphalt pavement mixtures, a study of parking needs and options on the WPI campus, an analysis of traffic accidents in Worcester, an economic study of the pros and cons of having trees in highway medians and ride quality study.

**URBAN AND ENVIRONMENTAL PLANNING**

The principal emphasis of urban design at WPI is the spatial arrangement of sites, neighborhoods, communities and regions, expressed through comprehensive site and development plans. These show the recommended uses of land such as residential, business, industrial, and recreational. The preservation of open space is also a major concern.

Key courses of this subarea are CE 3070, CE 3074, and CE 4071. Further depth in this field can be obtained by taking CE 4046 and selected graduate courses. An understanding of the other engineering areas will enhance the urban design area. Courses such as CE 3010, CE 3059, CE 2020, and CE 3026 will be helpful. Recent MQP topics include highway route selection, highway environmental impact, design of residential area and design of new towns, and GIS applications to planning.

**CONSTRUCTION ENGINEERING AND PROJECT MANAGEMENT**

The civil engineering program in construction engineering and project management is directed to students whose interests lie in the design engineering process but who are also concerned with the problems in social science, management, business, labor and legal relations, and the interaction of governmental and private interests as they relate to major construction projects.

Because of the multidisciplinary nature of the program, students are encouraged to complete courses in management. Information and control systems are important to construction management, and competence in utilizing computers in these areas is expected. Students are encouraged to work with the profession through projects and other activities. Key courses in the area are CE 3006, CE 3008, CE 3020, CE 3021, CE 3022, CE 3023, CE 3024, and CE 3030. An understanding of other engineering areas will enhance a construction engineering and management program. Courses such as CE 3044, CE 3050, CE 4071, and CE 3059 will be helpful. Typical project topics include computers in construction, prefabricated buildings, rehabilitative construction strategies, scheduling of construction projects, cost evaluation of construction, and integration of design and construction.

**ENVIRONMENTAL CONCENTRATION**

COORDINATORS: Profs. Bergendahl, Hart, Mathisen, O’Shaughnessy, and Plummer

Civil Engineering majors may choose to focus their studies by obtaining an Environmental concentration. An Environmental concentration in the CEE Department focuses on the planning, design, construction, operation and regulation of water quality systems related to water supply and waste treatment. Additional areas of focus include hydrology, hydraulics, solid and hazardous waste management, waste minimization, public health and air pollution control.

Students electing to pursue the Environmental concentration follow a general curriculum in Civil Engineering, with emphasis on the environmental engineering sub-area. Such preparation leads to a degree recognized by the professional accrediting organization, ABET (Accreditation Board of Engineering and Technology), and is an excellent start for entry-level professional placement or graduate study in environmental engineering.

The Environmental concentration is earned by completing six courses from the following list (or alternate courses through petition) plus an MQP in the environmental area. Typical MQPs include the analysis and design of innovative wastewater, water and solid waste treatment systems, disinfection processes, water quality monitoring and control system designs, water resources systems and groundwater studies.

- CE 3059 Environmental Engineering
- CE 3060 Water Treatment
- CE 3061 Wastewater Treatment
- CE 3062 Hydraulics
- CE 3070 Urban and Environmental Planning
- CE 3074 Environmental Analysis
- CE 4060 Environmental Engineering Laboratory
- CE 4061 Hydrology
- CE 4071 Land Use Development & Controls
- CHE 3201 Kinetics and Reactor Design
- CHE 3920 Air Quality Management

**MASTER BUILDER PROGRAM**

The Master Builder program has been designed to educate engineers with technical competency and management proficiency, able to effectively participate and play a leadership role in multi-disciplinary teams within the increasingly complex and demanding architectural/engineering/construction industry. These professionals are prepared to effectively integrate the planning, design construction and management of constructed facilities. They should be able to work for clients such as private developers and public agencies, traditional design, construction and facilities management firms as well as with integrated design-build firms.

**COMBINED-DEGREE PROGRAM**

**FIVE-YEAR PROGRAM**

High school seniors can be admitted to the combined-degree Master Builder Program as freshman, allowing them to complete both a bachelor of science and master of engineering degree in civil and environmental in five years.
The civil engineering part of the program has requirements, although no unique courses are specifically required to complete the program. Nevertheless, certain courses normally are considered a part of a civil engineering education, unless a strong basis for deviation exists. Consultation with an advisor will help an individual to construct a program that both meets WPI and ABET requirements and also provides a breadth and professional training in areas of interest. To provide guidance in structuring a program, the following courses normally should be considered as a basic expectation for all civil engineering programs:

### Course

<table>
<thead>
<tr>
<th>Course</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE 1030</td>
<td>Fundamentals of Computers and Civil Engineering</td>
</tr>
<tr>
<td>CE 2000</td>
<td>Analytical Mechanics I</td>
</tr>
<tr>
<td>CE 2001</td>
<td>Analytical Mechanics II</td>
</tr>
<tr>
<td>CE 3004</td>
<td>Fluid Mechanics</td>
</tr>
<tr>
<td>CE 2020</td>
<td>Surveying</td>
</tr>
<tr>
<td>CE 3041</td>
<td>Soil Mechanics</td>
</tr>
</tbody>
</table>

The following courses should be considered as fundamental to most civil engineering programs:

### Course

<table>
<thead>
<tr>
<th>Course</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE 2002</td>
<td>Introduction to Analysis and Design</td>
</tr>
<tr>
<td>CE 3026</td>
<td>Materials of Construction</td>
</tr>
<tr>
<td>CE 3030</td>
<td>Fundamentals of Civil Engineering AutoCAD</td>
</tr>
</tbody>
</table>

A cohesive program should include a selection of courses in the professional areas noted below. The student should incorporate courses in as many areas as practicable to develop a program that has both substance and breadth. Many of the courses have interactive applications in two or more engineering disciplines.

### Course

<table>
<thead>
<tr>
<th>Course</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE 3021</td>
<td>Cost Estimating, Scheduling, and Cost Control</td>
</tr>
<tr>
<td>CE 3022</td>
<td>Legal Aspects in Design and Construction</td>
</tr>
<tr>
<td>CE 3023</td>
<td>Architectural Engineering Systems</td>
</tr>
<tr>
<td>CE 3024</td>
<td>Control Surveying</td>
</tr>
<tr>
<td>CE 3060</td>
<td>Water Treatment</td>
</tr>
<tr>
<td>CE 3061</td>
<td>Waste Water Treatment</td>
</tr>
<tr>
<td>CE 3062</td>
<td>Hydraulics</td>
</tr>
<tr>
<td>CE 4060</td>
<td>Environmental Engineering Lab</td>
</tr>
<tr>
<td>CE 4061</td>
<td>Hydrology</td>
</tr>
<tr>
<td>CE 3044</td>
<td>Foundation Engineering</td>
</tr>
<tr>
<td>CE 4046</td>
<td>Experimental Soil Mechanics</td>
</tr>
<tr>
<td>CE 3006</td>
<td>Design of Steel Structures</td>
</tr>
<tr>
<td>CE 3008</td>
<td>Design of Reinforced Concrete Structures</td>
</tr>
<tr>
<td>CE 4007</td>
<td>Matrix Analysis of Structures</td>
</tr>
<tr>
<td>CE 4017</td>
<td>Prestressed Concrete Design</td>
</tr>
</tbody>
</table>
Transportation and Planning
CE 3050 Introduction to Transportation Engineering I
CE 3051 Introduction to Pavement Materials Design and Management I
CE 3070 Urban and Environmental Planning I
CE 3074 Environmental Analysis II
CE 4054 Soil and Bituminous Materials Laboratory I
CE 4071 Land Use Development and Controls I

COMPUTER SCIENCE

M. A. Gennert, Head;
D. Finkel, Associate Head


Associate Professors: M. Claypool, K. Fisler, M. A. Gennert, G. T. Heineman, K. A. Lemone, C. Ruiz, C. E. Wills

Assistant Professors: E. Agu, N. Heffernan, R. Lindeman, M. Mani

Professor of Practice: M. Ciardaldi, G. F. Pollice

Affiliated Associate Professor: G. N. Sarkozy

Instructor: G. Hamel

Mission Statement
The mission of the Computer Science Department at WPI is to provide outstanding education to its undergraduate and graduate students in accordance with the principles of the WPI mission, to advance scholarship in key domains of the computing sciences, and to engage in activities that improve the welfare of society and enhance the reputation of WPI. The Department aims to maintain an environment that promotes innovative thinking; values mutual respect and diversity; encourages and supports scholarship; instills ethical behavior; and engenders life-long learning.

Program Educational Objectives
The objectives established by the WPI Computer Science Program in support of its goals and mission are to graduate students with a Computer Science major who:
1. Are prepared technically for computer science and software engineering practice.
2. Understand the basic principles of computer science and software engineering.
3. Understand appropriate mathematical concepts and are able to apply them to computational problems.
4. Have knowledge of computer hardware and architecture.
5. Understand and follow the software engineering process.
6. Are prepared to design and implement software systems.
7. Are prepared to analyze and evaluate software systems.
8. Understand fundamental scientific principles and the scientific method.
9. Can function effectively in diverse teams and situations.
10. Can communicate effectively in speech and in writing.
11. Are able to learn independently and find relevant resources.
12. Are prepared for future changes in computer science and software engineering.
13. Are prepared to uphold professional and ethical standards.
14. Understand and appreciate the role of computer science and software engineering in a societal context.
15. Are aware of career and further educational opportunities.
16. Have a mature understanding of themselves and others.

Program Outcomes
Based on the above objectives, the specific outcomes to be achieved for the WPI Computer Science major are that:
1. All students will demonstrate an understanding of programming language concepts.
2. All students will demonstrate knowledge of computer organization.
3. All students will demonstrate an ability to analyze the behavior of computational systems.
4. All students will demonstrate knowledge of computer operating systems.
5. All students will demonstrate an understanding of the foundations of computer science.
6. Almost all students will demonstrate an understanding of software engineering principles and the ability to apply them to software design.
7. A majority of students will demonstrate an understanding of human-computer interaction.
8. All students will complete a large-scale software project.
9. All students will demonstrate advanced knowledge of computer science topics.
10. All students will demonstrate an understanding of the mathematical foundations of computer science.
11. All students will demonstrate knowledge of probability or statistics.
12. All students will demonstrate an understanding of scientific principles.
13. A majority of students will demonstrate the ability to design experiments and interpret experimental data.
14. All students will demonstrate independent learning.
15. All students will demonstrate the ability to locate and use technical information from multiple sources.
16. All students will demonstrate an understanding of professional ethics.
17. All students will demonstrate an understanding of the links between technology and society.
18. A majority of students will belong to at least one professional organization, including IEEE, ACM, and UPE.
19. All students will participate in a class or project team.
20. Almost all students will demonstrate the ability to communicate effectively in speech.
21. All students will demonstrate the ability to communicate effectively in writing.
Program Distribution Requirements for the Computer Science Major

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9) mathematics, basic science, and related fields as follows:

**COMPUTER SCIENCE**

<table>
<thead>
<tr>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Computer Science (including the MQP) (Notes 1, 2). 6</td>
</tr>
<tr>
<td>2. Mathematics (Notes 2, 3, 5). 7/3</td>
</tr>
<tr>
<td>3. Basic Science and/or Engineering Science (Notes 2, 4). 5/3</td>
</tr>
</tbody>
</table>

**NOTES:**
1. a. Only CS 1101, CS 1102 and computer science courses at the 2000-level or higher will count towards the computer science requirement. CS 2118 will not count towards the computer science requirement.
   b. Must include at least 1/3 unit from each of the following areas: Systems (CS 3013, CS 4513, CS 4514, CS 4515), Theory and Languages (CS 3133, CS 4120, CS 4123, CS 4533, CS 4536), Design (CS 3041, CS 3431, CS 3733, CS 4233), and Social Implications of Computing (CS 3043, STS 2208, GOV/ID 2314). (If STS 2208 or GOV/ID 2314 is used to satisfy this requirement, it does not count as part of the 6 units of CS.)
   c. At least 5/3 units of the Computer Science requirement must consist of 4000-level courses. These units can also be met by WPI graduate CS courses, with the exception of CS 501 and CS 507.
   d. Only one of CS 1101 and CS 1102 may count towards the computer science requirement. Only one of CS 2301 and CS 2303 may count towards the computer science requirement.

2. A cross-listed course may be counted toward only one of areas 1, 2, 3, above.
3. Must include at least 1/3 unit from each of the following areas: Probability (MA 2621, MA 2631) and Statistics (MA 2611, MA 2612).
4. Courses satisfying the science requirement must come from the BB, BME, CE, CH, CHE, ECE, ES, GE, ME, PH disciplines. At least three courses must come from BB, CH, GE, PH, where at least two courses are from one of these disciplines.
5. At most four 1000-level Mathematics courses may be counted towards this requirement.

The Computer Science Department offers a second program not accredited by the Computing Accreditation Commission of ABET and not bearing the title “Computer Science.” The distribution requirements for that program are:

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**COMPUTER SCIENCE PROGRAM CHART**

**COMPUTER SCIENCE**

Minimum 18/3

**CORE COURSES**

- CS 1101 or CS 1102, CS 2011, CS 2022, CS 2223, CS 2303, CS 3013, CS 3041, CS 3043, CS 3133, CS 3733

**SYSTEMS**

—Minimum 1/3

- CS 3013, CS 4513, CS 4514, CS 4515

**THEORY AND LANGUAGE**

—Minimum 1/3

- CS 3133, CS 4120, CS 4123, CS 4533, CS 4536

**DESIGN**

—Minimum 1/3

- CS 3041, CS 3431, CS 3733, CS 4233

**SOCIAL IMPLICATIONS**

—Minimum 1/3

- CS 3043, STS 2208, GOV/ID 2314

STS 2208, GOV/ID 2314 do not count toward the 18/3 CS units

**ADVANCED LEVEL COURSES**

—Minimum 5/3

**COMPUTER SCIENCE MQP**

—Minimum 3/3

**SCIENCE**

Minimum 5/3

Any BB, BME, CE, CH, CHE, ECE, ES, GE, ME, PH courses.

At least three courses must come from BB, CH, GE, PH, where at least two courses are from one of these disciplines.

**MATHEMATICS**

Minimum 7/3

At most four 1000-level Mathematics courses.

May include CS 2022, CS 4032 or CS 4033 if not used to satisfy the CS requirements.

**STATISTICS**

—Minimum 1/3

MA 2611, MA 2612

**PROBABILITY**

—Minimum 1/3

MA 2621, MA 2631
### Program Distribution Requirements for the Computers with Applications Major

<table>
<thead>
<tr>
<th>COMPUTERS WITH APPLICATIONS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Computer Science (including the MQP) (Notes 1, 2)</td>
<td>16/3</td>
</tr>
<tr>
<td>2. Mathematics (Note 2)</td>
<td>7/3</td>
</tr>
<tr>
<td>3. Basic Science (Notes 2, 3)</td>
<td>2/3</td>
</tr>
<tr>
<td>4. Application Area (Notes 2, 4)</td>
<td>5/3</td>
</tr>
</tbody>
</table>

**NOTES:**

1. a. Only CS 1101, CS 1102 and computer science courses at the 2000-level or higher will count towards the computer science requirement. CS 2118 will not count towards the computer science requirement.
b. Must include at least 1/3 unit from each of the following areas: Systems (CS 3013, CS 4513, CS 4514, CS 4515), Theory and Languages (CS 3133, CS 4120, CS 4123, CS 4533, CS 4536), Design (CS 3041, CS 3431, CS 3733, CS 4233), and Social Implications of Computing (CS 3043, STS 2208, GOV/ID 2314). (If STS 2208 or GOV/ID 2314 is used to satisfy this requirement, it does not count as part of the 16/3 units of CS.)
c. At least 5/3 units of the Computer Science requirement must consist of 4000-level courses. These units can also be met by WPI graduate CS courses, with the exception of CS 501 and CS 507.
d. The MQP must involve the application of computer science concepts to the Application Area specified in Requirement 4.
e. Only one of CS 1101 and CS 1102 may count towards the computer science requirement. Only one of CS 2301 and CS 2303 may count towards the computer science requirement.

2. A cross-listed course may be counted toward only one of areas 1, 2, 3, 4 above.

3. The two courses satisfying the science requirement must both come from one of the following disciplines: BB, CH, GE, PH.

4. This requirement is satisfied by a cohesive set of work from disciplines other than Computer Science. Work used for any other degree requirements cannot be used for the Application Area. At least 3/3 units must be course work at the 3000 level or higher. Independent Study/Project (ISP) work, if any, must be conducted under the supervision of a member of the faculty in that discipline.

**ADDITIONAL ADVICE**

For additional advice about course selections, students should consult with their academic advisor or the Computer Science Department Web site (http://www.cs.wpi.edu/Undergraduate/)

**INDEPENDENT STUDY**

Independent study and project work provide the opportunity for students, working under the direction of faculty members, to study or conduct research in an area not covered in courses, or in which the students require a greater depth of knowledge. The background required of a student for independent study work depends on the particular area of study or research.

**PROJECT OPPORTUNITIES**

Off-campus major qualifying projects are available at the Budapest Project Center, The Lincoln Laboratory Project Center, the Silicon Valley Project Center, the Sun Microsystems Project Center, and the Wall Street Project Center.

Projects are also available on campus, both to support the ongoing research activities of the faculty, and to expand and improve the applications of computers for service, education, and administration.

Additionally, the department supports IQPs in a number of areas including assistance with, and development of, computer science education at neighboring area schools.

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### COMPUTER SCIENCE MINOR

The Minor in Computer Science will consist of 2 units from Computer Science, with no more than one course at the 1000-level. The 2 units must include one of the following, each of which provides an integrating capstone experience:

- CS 3013 Operating Systems
- CS 3041 Human-Computer Interaction
- CS 3133 Foundations of Computer Science
- CS 3431 Database Systems I
- CS 3733 Software Engineering
- CS 4120 Analysis of Algorithms
- CS 4123 Theory of Computation
- CS 4233 Object-Oriented Analysis and Design
- CS 4241 Webware: Computational Technology for Network Systems
- CS 4341 Introduction to Artificial Intelligence
- CS 4432 Database Systems II
- CS 4445 Data Mining
- CS 4513 Distributed Computing Systems
- CS 4514 Computer Networks: Architecture and Implementation
- CS 4515 Computer Architecture
- CS 4533 Techniques of Programming Language Translation
- CS 4556 Programming Languages
- CS 4731 Computer Graphics
- CS 4732 Computer Animation

- any graduate-level CS course, except for CS501, CS505, CS507, CS552, or CS590
- 1/3 unit of another activity, for example an ISP, which is validated by a CS faculty member as a capstone.

Students interested in initiating work on a minor in CS are encouraged to ask the Computer Science Department to identify a faculty member to assist the student in structuring a minor. Prior to the initiation of a capstone experience students must inform the offering professor of their intent to use the experience as a capstone.

Majors in Computer Science and Computers with Applications do not qualify for a Minor in Computer Science.

ECE majors and Management Information Science majors should review the Operational Rules of the Minor at WPI to avoid problems with double counting CS courses. For general policy on the Minor, see the description on page 12.
ELECTRICAL AND COMPUTER ENGINEERING

F. J. LOOFT, HEAD; H. HAKIM, ASSOCIATE HEAD
ASSISTANT PROFESSORS: X. Huang, A. Klein, W. Lou, A. Wyglnski
PROFESSOR OF PRACTICE: R. Labonte
AFFILIATE PROFESSOR: R. H. Campbell
INSTRUCTORS: S. J. Bitar, S. M. Jarvis, J. Matthews

MISSION STATEMENT
To be prepared for employment as a contributing engineer and/or for graduate-level education, students within the ECE Department receive instruction that is balanced between theory and practice. In fact, much of our curriculum integrates theory and practice within each course. It is common to study new devices and techniques, and then immediately work with these devices/techniques in a laboratory setting. In response to the breadth of ECE, all students work with their academic advisor to develop a broad-based program of study. As with most engineering curricula, ECE study includes a solid foundation of mathematics and science. Discipline-specific study in ECE usually begins early in a student’s career — during the second half of the freshman year — with courses providing a broad overview of the entire field. During the sophomore and junior years, students learn the core analysis, design and laboratory skills necessary to a broad range of ECE sub-disciplines. When desired, specialization within ECE occurs during the junior and senior years. In addition, all students complete a major qualifying project (MQP). This project, typically completed in teams during the senior year, is an individualized design or research project that draws from much of the prior instruction. Utilizing the benefit of individualized instruction from one or more faculty members, students develop, implement and document the solution to a real engineering problem. Many of these projects are sponsored by industry, or are associated with ongoing faculty research. These projects form a unique bridge to the engineering profession.

PROGRAM EDUCATIONAL OBJECTIVES
The department educates future leaders of the electrical and computer engineering profession, with a program characterized by curricular flexibility, student project work, and active involvement of students in their learning. Through a balanced, integrated curriculum we provide an education which is strong both in the fundamentals and in state-of-the-art knowledge, appropriate for immediate professional practice as well as graduate study and lifelong learning. Such an education also prepares students broadly for their professional and personal lives, providing the basis for effective leadership and informed citizenship. The curriculum embraces WPI’s philosophy of education, and takes advantage of key components such as the Interactive Qualifying Project to develop technical professionals who possess the ability to communicate, work in teams, and understand the broad implications of their work.

PROGRAM OUTCOMES
Based on the department’s educational objectives, students will achieve the following specific educational outcomes within a challenging and supportive environment:
1. Preparation for engineering practice, including the technical, professional, and ethical components
2. Preparation for future changes in electrical and computer engineering
3. A solid understanding of the basic principles of electrical engineering, computer engineering, and the relationship between hardware and software
4. An understanding of appropriate mathematical concepts, and an ability to apply them to ECE
5. An understanding of the engineering design process, and ability to perform engineering design, including the needed teamwork and communications skills.
6. Demonstration of in-depth understanding of at least one specialty within ECE
7. An ability to communicate effectively in written and oral form
8. An understanding of options for careers and further education, and the necessary educational preparation to pursue those options
9. An ability to learn independently
10. The broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI
11. An understanding of engineering and technology in a societal and global context.

Program Distribution Requirements for the Electrical and Computer Engineering Major

The normal period of residency at WPI is 16 terms. In addition to WPI requirements applicable to all students, students wishing to receive the major designated “Electrical and Computer Engineering” must satisfy certain distribution requirements. These requirements apply to 10 units of study in the areas of mathematics, basic science, and engineering science and design as follows:

REQUIREMENTS MINIMUM UNITS
1. Mathematics and Basic Science (Notes 1a-1d) 4
2. Engineering Science and Design (ES/DD) (including the MQP) (Notes 2a-2g) 6

NOTES:
1. Mathematics and Basic Science:
a. Must include at least 7/3 units of math (prefix MA). Mathematics must include differential and integral calculus, differential equations, discrete mathematics, and probability and/or statistics.
b. Must include at least 2/3 units of physics (prefix PH).
c. Must include at least 1/3 units of chemistry (prefix CH) or 1/3 units biology (prefix BB).
d. Must include an additional 2/3 units of math or basic science (prefixes MA, PH, CH, BB, or GE).
2. Engineering Science and Design (including the MQP):
   a. Must include at least 5 units within the Electrical and Computer Engineering area (including the MQP). All courses with prefixes ECE (except ECE 3601) and ES 3011 are applicable to these 5 units.
   b. The 5 units within the Electrical and Computer Engineering area must include at least 1 unit of courses from these approved Electrical Engineering courses: ECE 2112, 2201, 2204, 2312, 3011, 3113, 3204, 3305, 3308, 3311, 3501, 3505, 4011, 4023, 4201, 4304, 4703, 4902, 4904, and ES 3011.
   c. The 5 units within the Electrical and Computer Engineering area must include at least 2/3 unit of courses from these approved Computer Engineering courses: ECE 2801, 3801, 3803, 3810 and 4801.
   d. The 5 units within the Electrical and Computer Engineering area must include 1/3 unit of Capstone Design Experience. (This requirement is typically fulfilled by the MQP).
   e. Must include at least 1/3 unit of computer science (prefix CS), at the 2000 level or above (other than CS 2011, CS 2022, CS 3043 which cannot be applied to this requirement).
   f. Must include at least 1/3 unit of engineering science (prefix ES) at the 2000 level or above. ES 3011 cannot be applied to this requirement.
   g. Must include an additional 1/3 unit of engineering science and design at the 2000 level or above, selected from courses having the prefix BME, CE, CHE, CS (other than CS 2011, CS 2022, CS 3043), ECE (other than ECE 3601), ES, FP, ME, or RBE.

SUBDISCIPLINES WITHIN ECE

Given a solid foundation, the MQP will allow you to demonstrate an in-depth understanding of one or more of the subdisciplines that compose the field of electrical and computer engineering. As a guide to the areas of study that can be investigated in an MQP, the ECE Course Flowchart identifies eight subdisciplines as possible areas for in-depth study leading to an MQP. Note that students should not feel constrained by these area designations — this is only one of many possible ways to organize the diverse field of electrical and computer engineering. Many if not most MQPs will incorporate subject matter from several different subdisciplines. The purpose of this list is to guide students interested in a particular area to coursework within a subdiscipline (Area Courses), relevant courses to choose from outside the subdiscipline (Related Courses), and faculty whose research and MQP advising interests fall within the subdiscipline (Area Consultants).

Robotics
Area Consultants: Cyganski, Duckworth, Looft, Michalson

Area Courses
- ECE 2022 Introduction to Digital Circuits and Computers
- ECE 2801 Foundations of Embedded Computer Systems
- ES 3011 Control Engineering I
- ECE 3803 Microprocessor System Design

Related Courses
- ECE 2201 Microelectronics I
- ECE 3305 Aerospace Avionics Systems
- ECE 3503 Power Electronics
- CS 4341 Artificial Intelligence
- RBE 1001 Introduction to Robotics
- RBE 2001 Unified Robotics I
- RBE 2002 Unified Robotics II
- RBE 3001 Unified Robotics III
- RBE 3002 Unified Robotics IV

Power Systems Engineering
Area Consultants: Emanuel, Hakim

Area Courses
- ECE 3501 Electrical Energy Conversion
- ECE 3503 Power Electronics

Related Courses
- ES 3001 Introduction to Thermodynamics
- ES 3011 Control Engineering I
- OIE 2850 Engineering Economics
- ME 1800 Materials Selection and Manufacturing Processes

RF Circuits and Microwaves
Area Consultants: Ludwig, Makarov

Area Courses
- ECE 2112 Electromagnetic Fields
- ECE 3113 RF Circuit Design

Related Courses
- MA 4451 Boundary Value Problems
- PH 3301 Electromagnetic Theory
- PH 3401 Quantum Mechanics I
- PH 3504 Optics

Communications and Signal Analysis
Area Consultants: Brown, Clancy, Cyganski, Hakim, Klein, Makarov, Pahlavan, Pedersen, Wyglinski

Area Courses
- ECE 2312 Discrete-Time Signal and System Analysis
- ECE 3204 Microelectronics II
- ECE 3311 Principles of Communication Systems
- ECE 3503 Power Electronics
- ECE 3803 Advanced Logic Design
- ECE 3803 Microprocessor System Design
- ECE 4304 Digital Communication Systems
- ECE 4703 Real-Time Digital Signal Processing

Related Courses
- ES 3011 Control Engineering I
- MA 2071 Matrices and Linear Algebra I
- MA 2621 Probability for Applications
- MA 4291 Applicable Complex Variables

Biomedical Engineering
Area Consultants: Clancy, Pedersen

Area Courses
- ECE/BME 2204 Bioelectric Foundations
- ECE/BME 3011 Bioinstrumentation and Biosensors
- ECE/BME 4011 Biomedical Signal Analysis
- ECE/BME 4023 Biomedical Instrumentation Design I
- ECE/BME 4201 Biomedical Imaging

Related Courses
- ECE 2312 Discrete-Time Signal and System Analysis
Basic Science” distribution requirement.

requires a total of 4 units (12 courses) as the “Mathematics and quality for any educated engineer. Consequently, the ECE major proficiency in mathematics and the sciences is a necessary the natural sciences. Moreover, whether applied to ECE or not, lecture, you must begin with a firm basis in mathematics and understand what your ECE professors are talking about in introductory courses. In fact, if you even want to begin to the necessary foundation far exceeds what can be taught in a few T o succeed in the study of electrical and computer engineering, MATHEMATICS AND SCIENCE departments.

The Engineering Science courses represent cross-disciplinary areas that are applicable to many engineering and science departments.

ENGINEERING SCIENCE AND DESIGN
Because modern engineering practice is increasingly interdisci-
plinary, all students achieve some breadth of study outside of the ECE department by taking a minimum of one Computer Science and one Engineering Science course. Both courses must be at the 2000-level or higher, and certain courses with limited technical content are not credited towards this requirement. (See the formal requirements listed previously in the distribution requirements.) In the Computer Science area, most students will need to complete a CS course at the 1000-level before attempting requirements at the 2000-level or above. Many students find it advantageous to take more than the minimum CS course requirement.

The Engineering Science courses represent cross-disciplinary areas that are applicable to many engineering and science departments.

MATHMATICS AND SCIENCE
To succeed in the study of electrical and computer engineering, the necessary foundation far exceeds what can be taught in a few introductory courses. In fact, if you even want to begin to understand what your ECE professors are talking about in lecture, you must begin with a firm basis in mathematics and the natural sciences. Moreover, whether applied to ECE or not, proficiency in mathematics and the sciences is a necessary quality for any educated engineer. Consequently, the ECE major requires a total of 4 units (12 courses) as the “Mathematics and Basic Science” distribution requirement.

The first part of this requirement is sufficient education in mathematics. At least 7 of the 12 required courses must be in this area, including coursework in differential calculus, integral calculus, differential equations, discrete mathematics, and probability and/or statistics. To see which specific courses fulfill these math requirements, please consult the mathematics course descriptions, the Planning a Program in ECE section, and your academic advisor.

The other part of the requirement is coursework in the sciences. A solid understanding of physics is essential to any ECE student, being ultimately necessary for describing the behavior of electricity and magnetism as well as other physical phenomena. Knowledge of chemistry is useful as well, encompassing such topics as atomic and molecular behavior and the chemical properties of materials (such as silicon, which is quite useful in ECE). In recent years, knowledge of biology has also become important to electrical and computer engineers, particularly as biomedical-electrical technologies such as medical imaging continue to advance.

The ECE major requires at least 3 courses in the sciences, 2 of these courses must be in physics, and the remaining course may be in chemistry or biology depending on preference.

Finally, note that the total prescribed mathematics and science courses add up to 3 1/3 units (10 courses). To meet the distribution requirement, you then must take at least 2 more courses in any area of mathematics or science (that is, any other course with the prefix “MA”, “PH”, “CH”, “BB”, or “GE”).

OVERVIEW OF OTHER PROGRAM COMPONENTS

MINOR IN COMPUTER ENGINEERING
This interdisciplinary minor requires students to develop competence in areas of computer engineering, including both hardware and software aspects of computer systems. This minor is not available to students majoring in Electrical and Computer Engineering.

Selected Rules for a Minor include the following:
1. Two or more units of thematically related activity.
2. Concluding 1/3 unit of the Minor must be a capstone experience.
3. A Minor may include any portion of the academic program, excluding the MQP.
4. At least one-unit of the Minor, including the capstone activity, must be free electives.
5. The Program Review Committee for a Minor area will consist of faculty members designated by the sponsoring faculty members.

In order to be eligible to receive the Computer Engineering Minor designation, at least six computer engineering related ECE and CS courses must be included in the distribution requirements, listed below. Other appropriate courses may be substituted with the approval of the Computer Engineering Minor Program Review Committee.
Every engineer, for example, needs to have some knowledge of graphics, the communications tool of engineering; of thermodynamics, the consideration of an important aspect of energy and its laws; of mechanics, solid and fluid, static and dynamic, the treatment of forces and their effects on producing motion. These and certain other courses of either basic knowledge or broad application are grouped in the engineering science series to provide special focus on them for all students interested in applied science or engineering. In developing programs to meet engineering science distribution requirements, students and advisors should give careful attention to these engineering science courses.

ENGINEERING PHYSICS

ADVISOR: G. S. Iannacchione

Programs of study in Engineering Physics are listed under the Physics Department. These programs include specialization in such areas as computational techniques, optics, electromagnetism, materials science and engineering, nuclear science and engineering, and thermal physics.

ENVIRONMENTAL PROGRAMS

Our relationship to the environment poses many and often complex problems. Solving these problems may require knowledge of science, technology, engineering, law, social policy, philosophy, history, literature, and the arts. In addition to enabling students to become effective scientists and engineers, programs offered at WPI can prepare students to pursue interests and careers in environmental journalism, environmental law, the EPA or other government programs, international contexts of development and conservation, environmental education, and professional environmental activism.

Students should review these programs as listed below, and talk with their academic advisors and the respective program coordinators, to help make a good choice of environmental major at WPI. In every program, the WPI project requirements, both in the major field and the IQP, will provide unusually strong support for defining specific career directions. Students are also urged to make use of the “Global Perspective Program” to carry out one project abroad, and thus attain a sense of environmental studies at a global, cross-cultural level.

For information, please contact Prof. Lance Schachterle, les@wpi.edu or 508-831-5514.
ENVIRONMENTAL ENGINEERING

DIRECTOR: J. Plummer (CEE)
ASSOCIATED FACULTY: J. Bergendahl (CEE), T. Camesano (CHE), W. Clark (CHE), D. DePaor (PH), D. DiBiasio (CHE), F. Hart (CEE), N. Kazantzis (CHE), P. Mathisen (CEE), J. O'Shaughnessy (CEE), B. Savlisis (ME), J. Sullivan (ME), R. Thompson (CHE)

MISSION STATEMENT
Environmental engineers are challenged not only with mastering technical and scientific principles, but also understanding the broader context within which environmental solutions are implemented. The environmental engineering program encourages coursework in the humanistic and social aspects of engineering decisions, public health management, and environmental preservation. The projects program at WPI offers environmental engineering students a unique opportunity to explore the complex humanistic, economic, legal, and political issues surrounding environmental engineering problems.

The Environmental Engineering degree program prepares students for careers in both the private and public sectors, consulting, industry, and advanced graduate study.

PROGRAM EDUCATIONAL OBJECTIVES
The educational objectives for the Bachelor degree in Environmental Engineering are that all graduates:
1. Are able to apply fundamental principles of mathematics, science, and engineering to solve water, air, and land environmental problems.
2. Have the interpersonal and communication skills, an understanding of ethical responsibility, and a professional attitude necessary for a successful engineering career.
3. Have the ability to engage in lifelong learning.
4. Have an appreciation for the interrelationships between basic scientific knowledge, technology, and societal issues.

PROGRAM OUTCOMES
The educational outcomes for the Bachelor degree in Environmental Engineering are that all graduates will:
1. Be prepared for engineering practice, including technical, professional, and ethical components.
2. Be prepared for future changes in environmental engineering.
3. Have a solid understanding of the basic principles of environmental engineering.
4. Demonstrate knowledge in the areas of water, land, and air systems, and environmental health.
5. Understand appropriate scientific concepts, and have an ability to apply them to environmental engineering.
6. Understand the engineering design process and have an ability to perform engineering design, which includes the multidisciplinary aspects of the engineering design process, the need for collaboration and communication skills, plus the importance of cost and time management.
7. Have the ability to collect, analyze and interpret experimental data.
8. Understand options for careers and further education, and the educational preparation necessary to pursue those options.
9. Have an ability to learn independently.
10. Have the broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI.
11. Have an understanding of the environmental engineering profession in a societal and global context.

Program Distribution Requirements for the Environmental Engineering Major
The normal period of residency at WPI is 16 terms. In addition to WPI requirements applicable to all students, students wishing to receive a degree designated “Environmental Engineering” must satisfy certain distribution requirements as follows:

REQUIREMENTS MINIMUM UNITS
1. Mathematics and Basic Science (Note 1) 4
2. Advanced Science (Note 2) 1
3. Engineering Science and Design (Includes MQP) (Note 3) 6

NOTES:
1. Mathematics and Basic Science
   a. Must include 6/3 units of mathematics, including differential and integral calculus, differential equations, and statistics.
   b. Must include 6/3 units of basic science, including 1/3 unit of biology (BB), 3/3 units of chemistry (CH), 1/3 unit of earth science (GE 2341 recommended) and 1/3 unit of PH (calculus based).
2. Advanced Science: Must include 3/3 units of science at the 2000-level or higher. Minimum of 1/3 unit in biology (BB) and 1/3 unit in chemistry (CH). Courses may not be double counted toward the basic science requirement.
3. Engineering Science and Design
   a. Must include 2/3 units in thermo-fluids, including 1/3 unit in fluid mechanics (ES 3004 recommended) and 1/3 unit in thermodynamics (ES 3001, CH 3501 or CHE 2013).
   b. Must include 2/3 units in mechanics and materials (CE 2500 or CE 2501, CE 2001 or CE 2502, ES 2001, CE 2503).
   c. Must include 3/3 units of Core Environmental Engineering (CHE 2011, CE 3059, CE 3062, CHE 3201).
   d. Must include 6/3 units in Environmental Engineering Electives, arranged as follows: 3/3 units in water quality and resources, 2/3 units in air and land environmental systems, and 1/3 unit in environmental management.
   e. Must include 1/3 unit of environmental health issues (CE 3059, CE 3060, CE 3061, or appropriate experience through IQP, independent study, or appropriate consortium courses).
   f. Must include 2/3 units with laboratory experimentation. Must include either CE 4060 or CHE 4401. The remaining 1/3 unit may be CE 4060, CHE 4401, laboratory courses in CH (CH 2640 or CH 2650, which would satisfy Advanced Science course requirements), CE 3026, or CE 2020.
   g. Must include 1/3 unit major design experience through the MQP, or other approved design experience in a course such as CHE 4403 or ME 4429.

For more information, please consult the web site for this major at http://wpi.edu/Academics/Majors/EVE/.
STUDENTS EARNING A BACHELOR DEGREE IN ENVIRONMENTAL ENGINEERING MUST COMPLETE A MINIMUM OF 15 UNITS OF STUDY, DISTRIBUTED AS FOLLOWS:

**MATHEMATICS AND BASIC SCIENCE (4 Units Required)**
- Differential and integral calculus; differential equations 5/3 units
- Statistics (MA 2611 recommended) 1/3 unit
- Biology (BB) 1/3 unit
- Chemistry (CH) 3/3 units
- Earth science (GE 2341 recommended) 1/3 unit
- Physics (PH, calculus-based) 1/3 unit

**ADVANCED SCIENCE (1 Unit Required)**
- 2000-level or higher courses. Minimum of 1/3 units in biology (BB) and 1/3 units in chemistry (CH). Courses may not be double counted toward the basic science requirement.

**ENGINEERING SCIENCE AND DESIGN (6 Units Required; 5 1/3 units as arranged below plus 2/3 units free electives in ES&D at the 2000-level or above).**
Please consult the program distribution requirements for detailed information on course requirements and selection.

**Engineering Science**

**Thermofluids**  minimum 2/3 units
- ES 3001 Introduction to Thermodynamics (or CHE 2013 or CH 3510)
- ES 3002 Mass Transfer
- ES 3004 Fluid Mechanics
- CHE 3501 Applied Mathematics in Chemical Engineering

**Mechanics and Materials**  minimum 2/3 units
- CE 2000 Analytical Mechanics I (or ES 2501)
- CE 2001 Analytical Mechanics II (or ES 2502)
- ES 2001 Introduction to Material Science
- ES 2503 Introduction to Dynamic Systems

**Core Environmental Engineering**  minimum 3/3 units
- CHE 2011 Chemical Engineering Fundamentals
- CE 3059 Environmental Engineering
- CE 3062 Hydraulics in Civil Engineering
- CHE 3201 Kinetics and Reactor Design

**Environmental Engineering Electives**

**Water Quality and Resources**  minimum 3/3 units
- CE 3060 Water Treatment
- CE 3061 Wastewater Treatment
- CE 4060 Environmental Engineering Laboratory
- CE 4061 Hydrology

**Air and Land Environmental Systems**  minimum 2/3 units
- CE 3041 Soil Mechanics
- CE 3074 Environmental Analysis
- CHE 3920 Air Quality Management
- CHE 4401 Unit Operations of Chemical Engineering I

**Environmental Management**  minimum 1/3 unit
- CE 3020 Project Management
- CE 3070 Urban and Environmental Planning
- CE 4071 Land Use Development and Controls

**Major Qualifying Project**  3/3 units

**ADDITIONAL DEGREE REQUIREMENTS (4 units Required)**
- Humanities and Arts  6/3 units
- Social Science‡  2/3 units
- IQP  3/3 units
- Physical Education  1/3 unit

‡ Many SS courses compliment topics in environmental engineering. Courses in policy, regulations, law and environmental problems are recommended.
ENVIRONMENTAL INTERESTS

Civil Engineering with Environmental Concentration

Coordinators: Profs. Bergendahl, Hart, Mathiesen, O’Shaughnessy, and Plummer, Civil and Environmental Engineering

Civil Engineering majors may choose to focus their studies by obtaining an Environmental concentration. An Environmental concentration in the CEE Department focuses on the planning, design, construction, operation and regulation of water quality control systems related to water supply and waste treatment. Additional areas of focus include hydrology, hydraulics, solid and hazardous waste management, waste minimization, public health and air pollution control.

Students electing to pursue the Environmental concentration follow a general curriculum in Civil Engineering, with emphasis on the environmental engineering sub-area. Such preparation leads to a degree recognized by the professional accrediting organization, ABET (Accreditation Board of Engineering and Technology), and is an excellent start for entry-level professional placement or graduate study in environmental engineering.

The Environmental concentration is earned by completing six courses from a prescribed list (or alternate courses through petition) plus an MQP in the environmental area. Typical MQPs include the analysis and design of innovative wastewater, water and solid waste treatment systems, disinfection processes, water quality monitoring and control system designs, water resources systems and groundwater studies.

For further information on the Environmental Concentration within Civil Engineering, please consult the Civil Engineering program description.

Chemical Engineering with Environmental Concentration

Coordinators: Profs. Cameano, Thompson, Ma, Dixon, DiBiasio, Kazantis, or Clark, Chemical Engineering

The Department of Chemical Engineering at WPI provides a general curriculum leading to an ABET-accredited degree in chemical engineering. Undergraduates can become involved in a specialty area of environmental engineering through their MQP or other independent projects, and are encouraged to work with faculty in their own areas of research in these fields. Today’s chemical engineers are challenged to help maintain industrial competitiveness while ensuring a healthy environment. Chemical engineers with environmental emphasis design and develop environmentally benign chemical processes aimed at preventing pollution at its source by recycling or eliminating all hazardous components. Additionally, they are involved in developing environmentally friendly products like biodegradable packaging materials. Chemical engineers’ understanding of the physical and chemical properties of pollutants makes them uniquely qualified to develop technical solutions to current environmental problems of soil, water, and air pollution.

Students majoring in this program would follow a general curriculum in Chemical Engineering, with elective coursework in environmental engineering and environmental related project work. Such preparation leads to a degree recognized by the professional accrediting organization, ABET (Accreditation Board for Engineering Technology), and is an excellent start for entry-level professional placement or graduate study in environmental engineering.

For information, please contact Prof. Robert Thompson, rwt@wpi.edu or 508-831-5525.

Semester In Environmental Science

Coordinator: Prof. D. Gibson, Biology & Biotechnology
Course work in marine ecology is available off campus through a cooperative arrangement with the Marine Biological Laboratory in Woods Hole. Each fall the Marine Biological Laboratory in Woods Hole and a consortium of colleges and universities sponsor a semester of study in environmental sciences, explored through the perspective of ecosystems ecology. Students participating in the SES will be housed and study at the Marine Biological Laboratory for 15 weeks. Study will include core courses in terrestrial and aquatic ecosystems, seminar series in science and science writing, and elective courses in specific areas of ecology and ecosystems. Each student will also complete an independent research project. Entrance into the program is competitive. Prospective applicants will be prescreened by a selection committee at WPI. Final applications are reviewed by a committee appointed by the director of MBL which makes the final selection.

For more information, please contact Prof. Daniel Gibson, dgibson@wpi.edu or 508-831-5144.

Environmental Policy and Development

Coordinators: Profs. Saeed or Rissmiller, Social Science and Policy Studies

The Department of Social Science and Policy Studies offers a degree program in Environmental Policy and Development that emphasizes sustainability. The program takes a multidisciplinary approach to environmental issues and includes coursework in economics, public policy, law, and psychology. Students can also pursue degrees in Economic Science, Society, Technology, and Policy, and System Dynamics with an environmental emphasis.

Students majoring in one of these SSPS programs will be prepared for entry-level professional work, or for graduate study either for the MBA or a master’s or doctoral research program.

For information, please contact Prof. Khalid Saeed, saeed@wpi.edu or 508-831-5563.

Humanities and Arts with Environmental Studies Concentration

Coordinator: Prof. R. Gottlieb, Humanities & Arts

The Humanities Department at WPI offers a general curriculum leading to degrees with concentrations in literature, philosophy and religion, and history. Students interested in humanistically-oriented environmental studies could major in the humanities, and take a specifically designed program involving one or more of these areas. Career possibilities upon graduation would include law, business, government service, environmental activism, journalism, or graduate study in the humanities.

For information, please contact Prof. Roger Gottlieb, gottlieb@wpi.edu or 508-831-5439.
Interdisciplinary Environmental Studies

Coordinator: Prof. R. Vaz, Interdisciplinary and Global Studies Division

Students wishing to design their own unique program in any field of environmental studies at WPI can do so through the Interdisciplinary and Global Studies Division (IGSD). Such a program might, for example, involve roughly equal areas of study in biology and biotechnology, chemical engineering, and social science and policy studies. Many other possible combinations also exist, with differing levels of study in both scientific and technological disciplines, and in social sciences, policy studies or humanities (ethics). Examples of areas for major study include (but are not limited to):

- identification and production of micro-organisms to remove heavy metals from the water supply, and
- technical writing for environmental organizations.

Interdisciplinary programs are coordinated through the IGSD, and advised by a panel of three faculty from different disciplines. Many students also explore the course offerings at Clark University and the College of the Holy Cross, which are available at no cost through the Worcester Consortium. Students with interdisciplinary programs will be prepared for entry-level professional employment or graduate study.

For information, please contact Prof. Rick Vaz, vaz@wpi.edu or 508-831-5547.

FIRE PROTECTION ENGINEERING

KATHY A. NOTARIANNI, HEAD
PROFESSOR: B. J. Savilonis
ASSOCIATE PROFESSORS: N. A. Dembsey, B. Meacham, L. Albano, F. Noonan, K. A. Notarianni
ASSISTANT PROFESSOR: A. Rangwala
AFFILIATE PROFESSORS: W. K. Kim, E. S. Yoon
EMERITUS PROFESSORS: R. W. Fitzgerald, R. E. Zalosh
DIRECTOR EMERITUS: D. A. Lucht

MISSION STATEMENT
To deliver a high quality fire protection engineering education program for both full-time students and practicing professionals, supported by fire research in selected areas of strength.

PROGRAM EDUCATIONAL OBJECTIVES
- To deliver a comprehensive fire protection engineering degree/certificate program that is consistent with changes in technology and the environment.
- To maximize the use of educational technology to deliver for-credit courses to both part time and full time students, on and off campus worldwide.

COMBINED BS/MS DEGREE PROGRAM
A combined-degree program is available for those undergraduate students having a strong interest in fire protection. This program provides students with the opportunity to accelerate their graduate work by careful development of their undergraduate plan of study leading to a Bachelor degree in a field of engineering and a master’s degree in fire protection engineering. The combined-degree approach saves time and money since up to 40 percent of course credits counted towards the Master’s degree can also be counted toward the Bachelor degree. Holders of a Bachelor degree in traditional engineering or science disciplines and the Master’s degree in fire protection engineering enjoy extremely good versatility in the job market.

FIRE PROTECTION ENGINEERING
FIVE-YEAR PROGRAM
High school seniors can be admitted to the combined-degree program as freshmen, allowing them to complete both a bachelor’s degree in a selected field of engineering and the master’s degree in fire protection engineering in five years.

HUMANITIES AND ARTS

J. P. HANLAN, INTERIM HEAD; P. H. HANSEN, ASSOCIATE HEAD
ASSOCIATE PROFESSORS: W. A. Addison, Jr., M. Ephraim, P. H. Hansen, L. D. Higgins, E. M. Parkinson, A. A. Rivera, J. Rudolph, M. D. Samson, R. L. Smith

MISSION STATEMENT
We are committed to helping students develop both a knowledge base and an ability to think critically about the humanities and arts. We also seek to foster the skills and habits of inquiry necessary for such learning: analytical thought, clear communication, and creative expression. An education, we believe, provides a crucial foundation for responsible and effective participation in a complex world.

Program Distribution Requirements for the Humanities and Arts Major

<table>
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<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
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<td>1. Humanities and Arts (including MQP) (Note 1)</td>
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</table>

NOTES:
1. Humanities and Arts majors may choose to complete 2 units of work and an MQP in one of the following areas of concentration: History, Literature, Music, Philosophy/Religion, Drama/Theatre, Writing and Rhetoric, Art or Art History, German Studies, Hispanic Studies, American Studies, Environmental Studies, or Humanities Studies of Science and Technology. The remaining 3 units of work may be from any area within the Humanities and Arts except that no less than 1 unit should be from an area of Humanities and Arts outside of the area of the student’s main concentration.
2. Must include 2/3 units in mathematics and 2/3 units in basic science. The remaining 2/3 unit may be from mathematics, basic science or computer science.
3. May be from any area except Air Force Aerospace Studies, Military Science, or Physical Education. Courses used to satisfy other degree requirements (i.e. the IQP) may not be used to fulfill this requirement.
CONCENTRATIONS FOR HUMANITIES AND ARTS MAJORS

Humanities and Arts majors may focus their studies by choosing a Concentration within a specific area of the Humanities and Arts, or within an interdisciplinary area closely related to the Humanities and Arts. Concentrations within the Humanities and Arts Department comply with WPI’s requirements for Concentrations. Students must complete an MQP and two units of integrated study in the area of their Concentration. Concentrations within the Humanities and Arts (History, Literature, Music, Philosophy, Religion, Drama/Theatre, Writing and Rhetoric, Art History, German Studies, Hispanic Studies) require two units of work in an area designated by specific disciplinary course prefixes, as described below. For example, a Concentration in History requires two units of HI courses at the 2000 level or higher and an MQP in history. Concentrations that are interdisciplinary in nature (American Studies, Environmental Studies, and Humanities Studies of Science and Technology) each require that courses be selected from specific lists of designated courses.

All of these Concentrations are excellent preparation for a variety of careers. Graduates of the Humanities and Arts major have gone to law, business, and medical schools, as well as to graduate programs in the discipline of their Humanities and Arts concentration. Some graduates have pursued careers as writers, teachers, engineers, or scientists. Other students have found work in the theatre as actors, technicians, or playwrights, or in music as composers or performers. The advantages our graduates find in their pursuit of further study and careers are the advantages of a rigorous study of the liberal arts: a good foundation in our cultural traditions and the cultural diversity of the world, and strong skills in research, analysis, writing, or performance.

In addition, since each Humanities and Arts major completes some technical work, either via the Distribution Requirements or a double major in a technical field, our graduates receive unique preparation as technological humanists. This educational experience gives them a distinct advantage in many fields in which a solid knowledge of engineering or science is increasingly valuable, such as environmental studies, drama/theatre, or business. The Humanities and Arts major equips students with vital general professional skills and with broad cultural and technical perspectives. Our many courses devoted to international issues or to foreign languages and the active involvement of Humanities and Arts faculty in the university’s global programs provides superb training for technological humanists interested in international issues. Whatever their specific area of concentration, majors in the Humanities and Arts gain an intellectual curiosity and openness to the diversity of human cultural achievements that will enrich their lives and enhance their careers.

REQUIREMENTS

**Humanities and Arts with History Concentration**
2 units of HI (2000 level or higher) and MQP in History

**Humanities and Arts with Literature Concentration**
2 units of EN, TH, or RH (2000 level or higher) and MQP in Literature

**Humanities and Arts with Music Concentration**
2 units of MU (2000 level or higher) and MQP in Music

**Humanities and Arts with Philosophy Concentration**
2 units of PY (2000 level or higher) and MQP in Philosophy

**Humanities and Arts with Religion Concentration**
2 units of RE (2000 level or higher) and MQP in Religion

**Humanities and Arts with Drama/Theatre Concentration**
2 units of TH, EN, or RH (2000 level or higher) and MQP in Drama/Theatre

**Humanities and Arts with Writing and Rhetoric Concentration**
2 units of RH, EN/WR, or TH (2000 level or higher) and MQP in Writing and Rhetoric

**Humanities and Arts with Art History Concentration**
2 units of AR or HU and MQP in Art History

**Humanities and Arts with German Studies Concentration**
2 units of GN (2000 level or higher) and MQP in German Studies

**Humanities and Arts with Hispanic Studies Concentration**
2 units in SP (2000 level or higher) and MQP in Spanish

HUMANITIES AND ARTS WITH AMERICAN STUDIES CONCENTRATION

This interdisciplinary concentration examines American culture from the multiple perspectives of American history, literature, and politics. American Studies at WPI takes advantage of the unparalleled resources at the American Antiquarian Society.

1. 1/3 units: one of the following courses: HU 1411 Introduction to American Studies, EN 1231 Introduction to American Literature, EN 1257 Introduction to African American Studies, HI 1312 Introduction to American Studies, HI 1313 Introduction to American Social History, or HI 1314 Introduction to Early American History.

2. 2/3 units from List 1 (“American History”)

3. 2/3 units from List 2 (“American Literature”)

4. 1/3 units from List 3 (“American Politics, Law, and Policy”). This may not include courses taken to fulfill the Social Science Requirement.

5. MQP in American Studies

List 1. American History:
HI 2311 American Colonial History
HI 2313 American History, 1789-1877
HI 2314 American History, 1877-1920
HI 2315 The Shaping of Post-1920 America
HI 2316 American Foreign Policy from Woodrow Wilson to the Present
HI 2317 Law and Society in America, 1865-1910
HI 2331 American Science and Technology to 1859
HI 2332 American Science and Technology from 1859
HI 3311 American Labor History
HI 3312 Topics in American Social History
HI 3314 The American Revolution
HI 3333 Topics in American Technological Development

List 2. American Literature:
EN 2221 American Drama
EN 2231 American Literature: The Raven, the Whale, and the Woodchuck
EN 2232 American Literature: Twain to the Twentieth Century
EN 2233 American Literature: Twentieth Century
EN 2234 Modern American Novel
EN 2235 The American Dream: Myth in Literature and the Popular Imagination
HUMANITIES AND ARTS WITH HUMANITIES STUDIES OF SCIENCE AND TECHNOLOGY CONCENTRATION

This interdisciplinary concentration enables students to apply to the methods of the humanities and social sciences to the study of science and technology.

1. 2/3 units from List 1 (“Designated HSST Courses”)
2. 2/3 units from List 1 or List 2 (“Closely Related Courses in Humanities”)
3. 2/3 units from List 3 (“Science-Technology-Studies Courses in Other Areas”). These may not include courses taken to fulfill the Social Science Requirement.
4. MQP in Humanities Studies of Science and Technology

List 1: Designated HSST Courses
AR 2113 Topics in 19th- and 20th-Century Architecture
EN 2252 Science and Scientists in Modern Literature
EN 3215 Genres of Science Writing
HI 1331 Introduction to the History of Science
HI 1332 Introduction to the History of Technology
HI 2300 History of American Science and Technology
HI 2333 History of Science from 1700
HI 2334 European Technological Development
HI 2351 History of Ecology
HI 2401 U.S. Environmental History
HI 2402 History of Evolutionary Thought
HI 3317 Topics in Environmental History
HI 3331 Topics in Science, Technology, and Society
PY 2713 Bioethics
PY 2717 Philosophy and the Environment

List 2: Closely Related Courses in Humanities
AR 3112 Modernism, Mass Culture, and the Avant-Garde
HI 1311 Introduction to American Urban History
HI 2324 Industry and Empire in British History
HI 3311 American Labor History
HI 3323 Topics in the Western Intellectual Tradition
PY 2711 Philosophical Theories of Knowledge and Reality

List 3: Science-Technology-Studies Courses in Other Areas.
AR/ID 3150 Light, Vision and Understanding and the Scientific Community
STS 1207 The Psycho-Sociology of Science
STS 2208 The Science-Technology Debate
GOV 2302 Science-Technology Policy
GOV 2304 Governmental Decision Making and Administrative Law
GOV 2311 Environmental Policy and Law
GOV 2312 International Environmental Policy

DOUBLE MAJOR IN HUMANITIES AND ARTS

Students may pursue a double major in Humanities and Arts and in an area of science, engineering, or management. To pursue the double major, a student must satisfy all of the degree requirements of the technical discipline including an MQP and Distribution Requirements. In addition, the double major in Humanities and Arts requires 6 units of studies in the Humanities and Arts, including the MQP. Students pursuing a double major, one of which is Humanities and Arts, are not required to
complete the Degree Requirement in Humanities and Arts, nor are they required to complete a second IQP. Students interested in pursuing this option should contact Prof. B. Addison, 39 Dean St., Room 260, for additional information.

The demand for graduates equipped with the background possessed by a WPI student with a double major in the Humanities and Arts is likely to increase. Many fields, including medicine, law, industry, theatre technology, commerce, and public service, will be open to those who have acquired both the skills of humanistic education and technical or managerial knowledge.

HUMANITIES AND ARTS MINORS

Minors can be arranged in areas other than the above. See Prof. Addison, 39 Dean Street, for further information about minors in other areas and interdisciplinary minors.

DRAMA/THEATRE MINOR

The minor in Drama/Theatre is for students who choose to continue their studies in Drama/Theatre beyond the Humanities and Arts Requirement without majoring in Drama/Theatre. Students who, for personal or career purposes, wish to earn official recognition of their achievements in Drama/Theatre, and who do not have academic time to fulfill the requirements for the major, should consider the Drama/Theatre minor.

Because performance, including design and production, is an integral component of Drama/Theatre, the requirements for this minor contain a performance emphasis. The Drama/Theatre minor consists of 2 units of work distributed as follows:

1. Drama/Theatre Courses: 1 1/3 units chosen from among the following:
   EN 1221, EN 1222, EN 2221, EN 2222, EN 2224, EN 3222, EN 3223, EN 3224, or any IS/P designated TH.
2. Drama/Theatre Performances: 1/3 unit (at least two 1/6 unit TH IS/P, Independent Study/Projects).
3. Drama/Theatre Capstone Experience: 1/3 unit Performance Independent Study/Project (EN or TH). The student, with faculty guidance, will perform, design, direct, produce or in some other way create a Drama/Theatre presentation that demonstrates the student’s skill and knowledge.

No more than 1 unit of work for the Humanities and Arts Requirement or Sufficiency Requirement may be applied to the Drama/Theatre minor. The final Inquiry Seminar or Practicum or Sufficiency Project may not be counted toward the minor.

Any student at WPI is eligible to pursue the Minor in Drama/Theatre except for students majoring in Humanities and Arts with a concentration in Drama/Theatre.

MINOR IN FOREIGN LANGUAGE (GERMAN OR SPANISH)

The minor in Foreign Language can be completed in either German or Spanish. It allows students who are well prepared to continue their study of the language and its culture well beyond the advanced level. The minor consists of a total of two units of work, distributed in the following way:

1. 1 unit of intermediate and advanced language courses in Spanish or German chosen from the following:
   • SP 2522, SP 3521, SP 3522, or higher or
   • GN 2512, GN 3511, GN 3512, or higher.
   (This unit may be double-counted toward the Humanities and Arts Requirement. No more than one unit may be double-counted in this way.)
2. 2/3 unit of advanced literature and culture courses chosen from the following:
   • SP 3523, SP 3524, SP 3525, SP 3526, or Consortium courses approved by a faculty member in Spanish or
   • GN 3513, GN 3514, or Consortium courses approved by a faculty member in German.
   • Any 3000-level experimental course in GN or SP may also be used.
3. 1/3 unit capstone experience consisting of an IS/P written in the foreign language.

(If, in the future, there are enough German and Spanish minors combined, the capstone independent study will be a team-taught seminar in comparative civilization/literature.) Interested students should see the following professors in the Humanities and Arts Department: Prof. Dollenmayer (for German) or Prof. Rivera and Prof. Manzari (for Spanish).

MUSIC MINOR

The minor in Music is for students who choose to continue their studies in Music beyond the Humanities and Arts Requirement without majoring in Music. Students who, for personal or career purposes, wish to achieve official recognition of their achievements in Music, yet do not find the time to fulfill the requirements for the major, should consider the Music minor option. Interested students should speak with one of the music faculty in the Department of Humanities and Arts. Because performance is an integral component of music study with proposed minor will contain performance emphasis and consist of two units of work distributed as follows:

1. 1/3 unit for participation in MU IS/P Ensembles.
2. 1/3 unit Performance IS/P as the capstone experience.
   Student, with faculty guidance, will present a recital, original composition, or other musical performance that demonstrates the student’s skill and knowledge.
3. 1 1/3 units of music courses.
4. If a student completes his/her Humanities and Arts Requirement in music, 1 unit of that work may be applied to the minor except for the final IS/P.
5. A student who is pursuing a major in Humanities and Arts with music as the major field cannot also receive a minor in music.
WRITING AND RHETORIC MINOR

The minor in Writing and Rhetoric offers students the opportunity to extend their study of writing and rhetoric beyond the Humanities and Arts Requirement without majoring in either the Writing and Rhetoric concentration in Humanities and Arts or the Technical, Scientific, and Professional Communication program. The minor consists of two units of work, distributed in the following way:

1. 2/3 unit. Core courses in writing and rhetoric: RH 3111, RH 3112
2. 1 unit. Electives in writing and rhetoric, chosen from the following: EN/WR 2210, EN/WR 2211, EN/WR 3011, EN/WR 3210, EN/WR 3214, EN/WR 3217 and RH 3211. If there is good reason and with the approval of the Program Review Committee, electives may also include courses in art history, literature (in English or other languages), and philosophy and religion.
3. 1/3 unit. Capstone IS/P.

No more than 1 unit of coursework may be double-counted toward the Humanities and Arts Requirement.

INDUSTRIAL ENGINEERING

DIRECTOR: S. A. JOHNSON

AFFILIATED FACULTY: A. Gerstenfeld, S. A. Johnson, A. Zeng, J. Zhu

MISSION STATEMENT

The mission of the Industrial Engineering (IE) Program at WPI is to prepare undergraduate students for professional engineering practice, providing the foundation for careers of leadership in challenging global and technological environments. We strive to accomplish this through:

- An innovative, project-based curriculum
- An emphasis on core industrial engineering skills with modern applications
- A flexible curriculum responsive to student interests and changes in the competitive environment
- An environment that encourages faculty/student interaction
- A culture that encourages the active involvement of students in their learning.

INDUSTRIAL ENGINEERING PROGRAM CHART

Note: This chart summarizes recommendations regarding course selection, sequencing, and timing. Students are encouraged to read the Program Distribution Requirements and Curriculum Guidelines for IE for more complete information. Students are also encouraged to arrange their programs to take advantage of global and cooperative education opportunities.

<table>
<thead>
<tr>
<th>FRESHMAN/SOPHOMORE</th>
<th>JUNIOR</th>
<th>SENIOR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COURSE RECOMMENDATIONS</strong></td>
<td><strong>IQP</strong></td>
<td><strong>MQP</strong></td>
</tr>
<tr>
<td>Calculus Sequence</td>
<td>OIE 2850</td>
<td>1 IE Elective</td>
</tr>
<tr>
<td>MA 1021, MA 1022, MA 1023, MA 1024, MA 2051</td>
<td>OIE 3401</td>
<td>2 Technical Electives</td>
</tr>
<tr>
<td>Statistics Sequence</td>
<td>OIE 3420 or OIE 3501</td>
<td>At least 3 Free Electives</td>
</tr>
<tr>
<td>MA 2611, MA 2612 or MA 2621</td>
<td>OIE 3460</td>
<td>Complete any remaining degree requirements</td>
</tr>
<tr>
<td>H&amp;A Sufficiency</td>
<td>Engineering Basics Outside IE</td>
<td></td>
</tr>
<tr>
<td>Physics/Chemistry Sequence</td>
<td>2 IE Electives:</td>
<td></td>
</tr>
<tr>
<td>PH 1110, PH 1120, CH 1010; or PH 1110, CH 1010, CH 1020</td>
<td>OIE 3405, OIE 3420, OIE 3450, OIE 3501, MIS 3720, OIE 4410, OIE 4460, MIS 4720, and OR courses in MA</td>
<td></td>
</tr>
<tr>
<td>CS 1101 or CS 1102</td>
<td>1 Technical Elective</td>
<td></td>
</tr>
<tr>
<td>Start IE Core:</td>
<td>Any engineering/science design course (see the IE web site for recommendations)</td>
<td></td>
</tr>
<tr>
<td>OIE 2500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OIE 3400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS 2118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Math/Science Electives</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DEGREE REQUIREMENTS</strong></td>
<td>IQP (1 unit)</td>
<td><strong>MQP (1 unit)</strong></td>
</tr>
<tr>
<td>H&amp;A Sufficiency (2 units)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math/Science (4 units)</td>
<td>Industrial Engineering Topics (5 units)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Science (2/3 units)</td>
<td></td>
<td>Free Electives (1 unit)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical Education (1/3 unit)</td>
<td></td>
</tr>
</tbody>
</table>
PROGRAM EDUCATIONAL OBJECTIVES

Educational objectives describe the expected accomplishments of graduates during the first few years after graduation.

1. Industrial Engineering Knowledge and Design Skills. Graduates should be able to support operational decision making and design solutions to address the complex and changing industrial engineering problems faced by organizations, using modern concepts and technology.

2. Communication Skills. Graduates should be able to communicate effectively, both orally and in writing, using electronic tools and graphical information.

3. Teamwork and Leadership Skills. Graduates should be able to serve as change agents in the organizations that employ them, based on strong interpersonal and teamwork skills, an understanding of professional and ethical responsibility and a willingness to take the initiative.

PROGRAM OUTCOMES

Program outcomes describe what students are expected to know and are able to do by the time of graduation, and are linked to the educational objectives described above.

1. Industrial Engineering Knowledge and Design Skills
   a. An ability to identify, formulate, and solve industrial engineering problems.
   b. An ability to design and conduct experiments, as well as to analyze and interpret data.
   c. An ability to design and improve integrated systems of people, materials, information, facilities and technology.
   d. An ability to apply core industrial engineering concepts, using the updated techniques, skills and tools necessary for industrial engineering practice.
   e. The broad education necessary to understand the impact of engineering solutions in a societal context.
   f. An ability to apply knowledge of mathematics, including statistics as well as integral and differential calculus.
   g. An understanding of fundamental physical laws.

2. Communication Skills
   h. An ability to communicate effectively.

3. Teamwork and Leadership Skills
   i. An ability to work effectively on multi-disciplinary teams.
   j. An understanding of professional and ethical responsibility.
   k. A recognition of the need for and an ability to engage in life-long learning.
   l. A knowledge of contemporary issues.
   m. An understanding of global issues.
   n. An understanding of change management in organizational settings.

Program Distribution Requirements for Industrial Engineering Major (IE)

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9), students wishing to receive the ABET accredited degree designated “Industrial Engineering” must complete a minimum of 10 units of study in the areas of mathematics, basic science, and engineering topics as follows:

REQUIREMENTS MINIMUM UNITS
1. Mathematics and Basic Science (Notes 1, 2) 4
2. Industrial Engineering Topics (including the MQP) (Notes 3,4) 6

NOTES:
1. Mathematics must include differential and integral calculus, ordinary differential equations, and 2/3 units in probability and statistics.
2. Basic Science must include both chemistry and physics, with a minimum of two courses in either.
3. Must include 1/3 unit of Capstone Design Experience.
4. Industrial Engineering Topics must include courses in the following three topic areas.
   a. 3 units of industrial engineering core courses, including 1/3 unit in each of the following 9 areas: engineering basics outside industrial engineering, deterministic operations research methods, process design, production planning and control, simulation, stochastic methods in operations research, information systems design, financial modeling and organizational science.
   b. 1 unit in Industrial Engineering electives 3000/4000 level OIE courses, MIS 3720, MIS 4720, and Operations Research courses in Mathematics qualify. Courses in financial modeling and organizational science do not qualify.
   c. 1 unit in technical electives. Industrial Engineering electives and any other Engineering Science/Design courses qualify.

INTERACTIVE MEDIA AND GAME DEVELOPMENT

DIRECTOR: M. CLAYPOOL (CS)
CO-DIRECTOR: D. O’DONNELL (HUA)


PROGRAM OUTCOMES

The specific outcomes for the WPI IMGD major are that all graduates will:
1. Understand Artistic and Technical areas related to IMGD.
2. Demonstrate an in-depth understanding of either the Artistic or Technical area related to IMGD.
3. Have a base of technical knowledge in Computer Science, Mathematics and Science.
4. Have a base of artistic knowledge in Art, Music and English.
5. Successfully complete a large-scale IMGD project.
6. Successfully complete a group project with both Technical and Artistic IMGD majors.
7. Be able to creatively express and analyze artistic forms relative to IMGD.
8. Communicate effectively orally, in writing, and in visual media.
9. Be aware of social and philosophical issues pertaining to games and related media.

Program Distribution Requirements for the Interactive Media and Game Development Major

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core IMGD (Note 1)</td>
<td>2/3</td>
</tr>
<tr>
<td>Math</td>
<td>1/3</td>
</tr>
<tr>
<td>Science</td>
<td>1/3</td>
</tr>
<tr>
<td>Computer Science (Note 2)</td>
<td>1/3</td>
</tr>
<tr>
<td>Social and Philosophical Issues (Note 3)</td>
<td>1/3</td>
</tr>
<tr>
<td>Studio Art (Note 4)</td>
<td>1/3</td>
</tr>
<tr>
<td>Computer Music (Note 5)</td>
<td>1/3</td>
</tr>
<tr>
<td>English (Note 6)</td>
<td>1/3</td>
</tr>
<tr>
<td>Advanced IMGD (Note 7)</td>
<td>2/3</td>
</tr>
<tr>
<td>Major Qualifying Project</td>
<td>3/3</td>
</tr>
</tbody>
</table>

In addition to the requirements listed above, students must satisfy one of the two area requirements, Technical (Computer Science) or Artistic (Humanities and Arts):

<table>
<thead>
<tr>
<th>AREA</th>
<th>MINIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Science (Note 8)</td>
<td>10/3</td>
</tr>
<tr>
<td>Humanities and Arts (Notes 9, 10, 11)</td>
<td>10/3</td>
</tr>
</tbody>
</table>

Students have electives that can be tailored to meet specific degree requirements and interests:

<table>
<thead>
<tr>
<th>ELECTIVES</th>
<th>MINIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Electives (Notes 12, 13)</td>
<td>6/3</td>
</tr>
</tbody>
</table>

NOTES:
1. Choose from: Critical Studies of Interactive Media and Games (IMGD 1000), The Game Development Process (IMGD 1001), Storytelling in Interactive Media and Games (IMGD 1002).
2. CS 2022 and CS 3043 may not be used to satisfy this requirement.
5. Choose from: Computer Techniques in Music (MU 3611), Computers and Synthesizers in Music (MU 3612), or Digital Sound Design (MU 3613).
6. Courses with the prefix EN or WR.
7. Taken from 2 technical offerings (IMGD 3000 and IMGD 4000) or 2 artistic offerings (IMGD 3500 and IMGD 4500).
8. At least 4/3 from: Human-Computer Interaction (CS 3041), Software Engineering (CS 3733, CS 4233), Computer Architecture (CS 4515), Computer Networks (CS 4514), Graphics (CS 4731), Animation (CS 4732), or Artificial Intelligence (CS 4341).
9. At least 1/3 from each of the following areas: Art, Music and English.
10. At least 5/3 units at the 2000-level or higher.
11. Students completing the Artistic (Humanities and Arts) Area Requirement must complete a Technical Requirement, described below.
12. Electives must be chosen from the following areas: Computer Science, Humanities and Arts, Interactive Media and Game Development, Mathematics, Science, Social Science, Management, or Engineering.
13. At least 3/3 units must be in a single one of the areas listed in Note 12.

TECHNICAL REQUIREMENT
Each student choosing the Artistic IMGD area will fulfill a Technical Requirement consisting of six courses as follows:

A. Courses required for all IMGD majors:
   1. One Mathematics Course
   2. One CS course, not including CS 2022 or 3043
   3. One Science (BB, CH, GE, PH) course

B. Additional requirements:
   4. A second course in Computer Science, not including CS 2022 or 3043
   5. Two additional courses from among Mathematical Sciences, Computer Science, Science (BB, CH, GE, PH) and Engineering (BME, CE, CHE, ECE, ES, FPE, ME), not including CS 3043.

The courses for the Technical Requirement, part A, are satisfied by the IMGD distribution requirements. The courses in part B may not double-count towards other IMGD requirements, including IMGD elective courses.

INTERDISCIPLINARY PROGRAMS

R. F. VAZ, DEAN
K. RISSMILLER, ASSOCIATE DEAN
ASSISTANT PROFESSORS: R. Krueger, S. Justo,
ADJUNCT PROFESSOR: S. Vernon-Gerstenfeld
ADJUNCT ASSISTANT PROFESSORS: F. Carrera, D. Golding, C. Peet

The Provost Office, in conjunction with the Interdisciplinary and Global Studies Division (IGSD), operates those academic functions or programs which require an interdisciplinary administrative structure. In addition, the IGSD also provides the support structure for students who construct individually-designed (ID) majors which cannot readily be accommodated in traditional academic departments.

ID majors may be defined in any area of study where WPI's academic strengths can support a program of study, and in which career goals exist. Many combinations of technical and non-technical study are possible. Do not be limited by the example given here; if you have questions about what programs at WPI are possible, please see Prof. R. Vaz in the Project Center to discuss how WPI can assist you in reaching your goals.

Procedure for Establishing an Interdisciplinary (Individually-Designed) Major Program

Students who wish to pursue an individually-designed major program should first discuss their ideas with their academic advisor. The student should then consult with the dean of the IGSD, Prof. Richard Vaz, who will determine, with the assistance of other members of the faculty, if the proposed program is feasible, and, if it is, arrange for its evaluation.

The following procedures will be followed for feasible programs:

1. The student must submit to the dean of the IGSD an educational program proposal, including a “definition of scope,” and a concise statement of the educational goals of the proposed program. Goals (such as graduate school or employment) should be specified very clearly. The proposal must be detailed in terms of anticipated course and project
work. The proposal must be submitted no later than one calendar year before the student’s expected date of graduation, and normally before the student’s third year.

2. The Dean of the Interdisciplinary and Global Studies Division will name a three-member faculty committee, representing those disciplines most involved in the goals of the program, to evaluate the proposal. The committee may request clarification or additional information for its evaluation. The proposal, as finally accepted by the committee and the student, will serve as an informal contract to enable the student to pursue the stated educational goals most effectively.

3. Upon acceptance of the proposal, the student will notify the Office of Academic Advising and the Projects and Registrar’s Office of the choice of ID (individually-designed) as the designation of major. The IGSD then becomes the student’s academic department for purposes of record-keeping.

4. The three-person faculty committee will serve as the student’s program advisory committee, and will devise and certify the distribution requirements (up to a limit of 10 units including the MQP) appropriate to the student’s program.

The programs below are the established majors administered through IGSD.

PROFESSIONAL WRITING

DIRECTOR: C. DEMETRY (ME)
ASSOCIATED FACULTY: M. Elmes (MG), L. Higgins (HUA),
K. Lemone (CS), A. Rivera (HUA), R. Smith (HUA)

The goal of the Professional Writing program is to prepare communication professionals who can bridge the gap between the public and scientists, engineers, physicians, managers, policymakers, and other experts by presenting technical information in useful and accessible ways.

Professional Writing is an interdisciplinary major or double major that combines work in written, oral, and visual communication with a strong concentration in a scientific or technical field. Students receive individual attention from academic advisors as they design a plan of study that fulfills the program’s distribution requirements and best suits their intellectual interests and career aspirations. If they wish, majors can select courses and projects in one of four areas of concentration:

• Science writing, medical writing, health communication
• Writing in the public interest, writing for nonprofits
• Digital media, visual communication, information design
• Bilingual professional communication, translation

The Professional Writing major provides excellent preparation for students interested in careers in technical and scientific communication, writing and editing, web authoring, information design, public relations, medical writing, translation, and intercultural communication. It also prepares students for graduate work in fields such as writing and rhetoric, technical communication, journalism, education, law, public health and medicine, and the study of culture.

MQP opportunities are available on campus and with local companies, newspapers, public agencies, and private foundations. More information about project and career opportunities for Professional Writing majors can be found on the program web site: www.wpi.edu/Academics/Majors/PWR.

Program Distribution Requirements for the Professional Writing Major

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scientific and/or technical concentration</td>
<td>6</td>
</tr>
<tr>
<td>(Note 1)</td>
<td></td>
</tr>
<tr>
<td>2. Writing and Rhetoric concentration (Note 2)</td>
<td>3</td>
</tr>
<tr>
<td>3. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTES:

1. The student’s scientific and/or technical concentration must be a plan of study, approved by the student’s program review committee, with a clear underlying rationale in mathematics, basic science, computer science, engineering, and/or management.

2. The Writing and Rhetoric concentration consists of 1 unit in each of the following categories: professional communication, technical writing, and rhetorical and critical thinking. Courses taken to fulfill these distribution requirements will not include courses that fulfill other degree requirements, such as the Humanities and Arts requirement and the Social Sciences requirement. Exceptions to this restriction, not to exceed 1 unit, must be approved by the student’s program review committee, and will be granted only under unusual circumstances.

A. Written communication (1 unit)

Recommended courses:
EN/WR 2210 Introduction to Professional Writing
EN/WR 2211 Elements of Writing
EN/WR 3011 Peer Tutoring in Writing
EN/WR 3210 Technical Writing
EN/WR 3214 Writing About Disease and Public Health

B. Rhetoric and communication studies (1 unit)

Recommended courses:
RH 3111 The Study of Writing
RH 3112 Rhetorical Theory
RH 3211 Rhetoric of Visual Design

C. Electives (1 unit)

The 1 unit of electives must be coherently defined and approved by the student’s program review committee.

Students may choose from:
Courses in science, technology, and culture studies (such as AR/ID 3150, CS 3041, CS 3043, EN 2252, HI 2330, HI 2334, HI 2402, HI 3331, HI 3333, HI 3334, HI 3342, IMGD 2000, IMGD 2001, STS 2208, GOV 2302, PSY 2406);
Philosophy and ethics courses (such as PY 2711, PY 2713, PY 2714, PY 2716, PY 2717, PY/RE 2731, PY/RE 3731);
Foreign language courses;
Management courses.

TEACHER LICENSING

WPI students wishing to receive the Initial License as middle or high school teachers in Massachusetts or states with reciprocating agreements with MA in the areas of Biology, Chemistry, Mathematics or Physics can do so by passing the Massachusetts MTEL test, taking a Teaching Methods course (ID 3100), performing observation and practice teaching and developing an IQP based on this experience, and taking Psychology of Education (PSY 2401) and Cross-Cultural Psychology (PSY 2406). Also required are courses in the appropriate subject matter meeting State guidelines as defined in Massachusetts regulations (603 CMR 7.00). Students wishing to discuss or pursue this should see Professor John Goulet (MA) and/or see http://users.wpi.edu/~goulet/teacher_prep/teacher_prep.htm.
INTernational Studies

P.H. Hansen, Director

Associated Faculty: W.A.B. Addison (HU), U. Brisson (HU), F. Carrera (IGSD), D.B. Dollenmoyer (HU), A. Gerstenfeld (MG), D. Golding (IGSD), P.H. Hansen (HU), R. Hersh (IGSD), S. Jiusto (IGSD), R. Krueger (IGSD), I. Matos-Nin (HU), C. Peet (IGSD), M.J. Radzicki (SSPS), K.J. Rissmiller (SSPS), A. Rivera (HU), T. Robertson (HU), J. Rudolph (HU), K. Saeed (SSPS), S. Tuler (IGSD), R. Vaz (IGSD; ECE), S. Vernon-Gerstenfeld (IGSD)

International Studies prepares men and women for future leadership roles in business and industry, government and public affairs. International Studies integrates WPI's international courses in the humanities and social sciences with its global projects and exchange programs. International Studies courses on-campus prepare students to go abroad. After an experience overseas, students integrate their experiences and explore their career options in a capstone seminar. International Studies at WPI offers a range of options including a minor, major, or double major in International Studies.

Program Requirements for the International Studies Minor

<table>
<thead>
<tr>
<th>INTERNATIONAL STUDIES IQP OPTION</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Core (Note 1)</td>
<td>1</td>
</tr>
<tr>
<td>International Electives (Note 2)</td>
<td>1</td>
</tr>
<tr>
<td>International IQP (Note 3)</td>
<td>1</td>
</tr>
<tr>
<td>International Experience (Note 4)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INTERNATIONAL STUDIES EXCHANGE PROGRAM OPTION</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Core (Note 1)</td>
<td>1</td>
</tr>
<tr>
<td>International Electives (Note 2)</td>
<td>2</td>
</tr>
<tr>
<td>International Experience (Note 4)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

NOTES:
1. International Core. Both options require the same one unit core of international courses. One course must be selected from each of these categories:
   a) An introductory course in international history, such as HI 1341, HI 1321, HI 1322, HI 1323, or HI 1313.
   b) A course in understanding cross-cultural differences, such as one of the following: HU 3411 Pro-Seminar in Global Perspectives, PSY 2406 Cross-Cultural Psychology, SOC 1202 Introduction to Sociology and Cultural Diversity, PY 2716 Philosophy of Difference.
   c) HU 4411 Senior Seminar in International Studies.

Distribution Requirements for the International Studies Major

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Core (Note 1)</td>
<td>1</td>
</tr>
<tr>
<td>International Fields (Note 2)</td>
<td>4</td>
</tr>
<tr>
<td>International Experience (Note 3)</td>
<td>0</td>
</tr>
<tr>
<td>Science, Technology, Mathematics (Note 4)</td>
<td>2</td>
</tr>
<tr>
<td>Electives (Note 5)</td>
<td>2</td>
</tr>
<tr>
<td>MQP</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>

NOTES:
1. International Core: One course must be selected from each of these categories:
   a) An introductory course in international history, such as HI 1341 or HI 1313, HI 1321, HI 1322, HI 1323.
   b) A course in understanding cross-cultural differences, such as one of the following: HU 3411 Pro-Seminar in Global Perspectives, or SOC 1202 Introduction to Sociology and Cultural Diversity, or PSY 2406 Cross-Cultural Psychology, or PY 2716 Philosophy of Difference.
   c) HU 4411 Senior Seminar in International Studies.

2. International Fields: Majors complete at least one unit of work in each of the following areas. They must also complete at least one additional unit of work in one of these areas, which will be considered their primary field.
   a) Historical Analysis. These include any courses in European history, world history, or American foreign policy.
   b) Language, Literature, and Culture. These include any course in foreign languages, civilization, and literature offered at WPI or in the Consortium with the prior approval of the Program Review Committee; also courses approved by the Program Review Committee in Art History (e.g., AR 1111, AR 2111), English Literature (e.g., EN 2243, EN 3223), Music History (e.g., MU 2615), or Philosophy and Religion (e.g., RE 2721, RE 2724). Majors who designate Language, Literature, and Culture (LLC) as their primary field may not take courses in a second foreign language unless they have achieved 3000-level proficiency in the first. LLC designees should take most of their courses in a single discipline or in a coherent program approved by the Program Review Committee.
   c) Social Sciences. These include international courses in the social sciences (e.g., GOV 1320, ECON 2125, GOV 2312, PSY 2406). Students may count courses taken for the two-course requirement in Social Sciences.
3. International Studies majors are required to have a study-abroad experience. (In very unusual cases exceptions may be made to this requirement but only with prior approval of the Director and Program Review Committee.) This abroad experience may take the form of a project, exchange, or internship approved by the Program Review Committee. The study-abroad experience should be educational in nature and equivalent in length to at least one WPI term.

4. Must include a minimum of 1/3 unit in science, 1/3 unit in mathematics, 1/3 unit in computer science or engineering science. The remaining 1 unit may be from science, mathematics, computer science or engineering. Double-majors may count courses taken for their other major.

5. Electives may be from any area except Air Force Aerospace Studies, Military Science or Physical Education. Double-majors may count courses taken for their other major.

**DOUBLE MAJOR IN INTERNATIONAL STUDIES**

Students may pursue a double major in International Studies and any area of study at WPI except a major in Humanities and Arts. To pursue the double major, a student must satisfy all of the degree requirements for both disciplines, including an MQP and Distribution Requirements. In addition, the double major in International Studies requires the same distribution of courses in the International Core and International Fields as the major in International Studies and a second MQP in International Studies. Double majors are also required to have an International Experience. Students pursuing the double major in International Studies are not required, however, to complete a Humanities and Arts Sufficiency program.

**INTERNATIONAL EXPERIENCES**

An International Experience may take the form of an international IQP or exchange program. Students often plan their international experience in their Sophomore year. All students are advised to consult the list of projects offered at WPI's Global Project Centers. Each fall, the projects and exchange programs for the following year are widely advertised on campus. For information about student exchange programs, see page 183.

Award-winning projects at WPI are frequently on international topics. Recent examples include studies of a workshop for the blind in London, chemical accidents in Bangkok, the social impact of the building code in New Zealand, and the use of biogas in Botswana. International Studies offers the opportunity not only to complete some of the highest quality projects at WPI, but also to offer solutions to some of the most challenging problems in the world.

Students interested in International Studies may ask any member of the Associated Faculty for more information, or they may consult our page on the World Wide Web: http://www.wpi.edu/-IN/.

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**LAW AND TECHNOLOGY MINOR**

As science and technology evolve, there are growing needs for professionals who both understand science and technology and who work within the institutions of the American legal system. At all levels, from federal courts to state regulatory agencies and local planning commissions, policy makers decide issues in an environment of legal rules and principles. Yet to be effective, they must also understand how science and technology can aid their decisions, the methods and conclusions of scientific research, and the social impact of decisions. Without science, environmental regulators cannot decide on measures for hazardous waste disposal, public health officials cannot evaluate new drug therapies, utility regulators cannot authorize new sources of electric power, judges cannot construe the meaning of medical testimony, and attorneys cannot cross examine an expert witness in a product failure case. Decision makers, and those who attempt to influence them, find that they need to understand science and technology.

The Law and Technology Program is an interdisciplinary minor that can be used to supplement a major, introduce students in science and engineering disciplines to legal studies and prepare students to enter law school upon graduation. Students in the program begin their studies with a foundation in legal institutions and analysis and continue with advanced courses that integrate law and technology. A course in professional communication is also required. Students complete their studies with a capstone research activity either in the sixth course or as a separate independent study.

To attain a Minor in Law and Technology, students must complete two units of study (6 courses) as follows:

1. Two of the following courses in legal fundamentals:
   - HI 2317 Law and Society in America, 1865-1910
   - GOV 1310 Law, Courts and Politics
   - GOV 2310 Constitutional Law: Foundations
   - GOV 2320 Constitutional Law: Civil Rights and Liberties
   - BUS 2950 Business Law and Ethics

2. Two of the following courses which integrate law and technology:
   - CE 3022 Legal Aspects in Design and Construction
   - CE 4071 Land Use Development and Controls
   - GOV 2302 Science-Technology Policy
   - GOV 2311 Environmental Policy and Law
   - GOV 2313 Intellectual Property Law
   - GOV/ID 2314 Cyberlaw and Policy

3. One of the following courses in professional communication:
   - EN/WR 2210 Introduction to Professional Writing
   - EN/WR 2211 Elements of Writing
   - EN/WR 3214 Writing About Disease and Public Health
   - RH 3112 Rhetorical Theory

4. One of the following courses undertaken as a capstone experience:
   - GOV 2304 Governmental Decision Making and Administrative Law
   - GOV 2312 International Environmental Policy

If a student takes both GOV 2304 and GOV 2313, the first one taken will count among courses that integrate law and technology, point 2., above. Minors enrolled in either course for their capstone experience will be required to complete the usual course requirements and an additional research paper. In the paper, the student will summarize existing law in an area of student interest, identify problems with the law, evaluate proposals for change and recommend legislative changes.

As an alternative, students may complete the capstone requirement as an independent study (IS/P) course with the approval and participation of one of the associated faculty.

Students should review their program of study with the associated faculty and/or pre-law advisor. Students are also encouraged to seek IQP opportunities in Division 52, Law and Technology. See page 18. Note: only one of the two units may be counted toward other college requirements.

For general policy on the Minor, see description on page 12.
LIBERAL ARTS AND ENGINEERING (BACHELOR OF ARTS DEGREE)

DIRECTORS: JOHN ORR (ECE), LANCE SCHACHTERLE (HU)
ASSOCIATED FACULTY and PROGRAM COMMITTEE:
David DiBiasio (Che), James Doyle (SSPS), Peter Hansen (HU),
Rob Krueger (IGSD), Kent Rissmiller (IGSD and SSPS),
D. Samson (HU), Grettar Tryggvason (ME),
Richard Vaz (IGSD and ECE)

MISSION STATEMENT
The goal of the Liberal Arts and Engineering Bachelor of Arts (BA) degree is to provide an opportunity for students who want a broad background in engineering and other disciplines, as preparation for further studies in engineering or in other fields such as medicine, law, public policy, international studies, business, or wherever a solid technical background would give them a unique edge. The program is also designed to allow students to transfer to an engineering BS program with minimum loss of time.

For more information, see the Admissions web site at http://www.wpi.edu/Academics/Majors/LAE/index.html.

PROGRAM EDUCATIONAL OBJECTIVES
The Liberal Arts and Engineering degree recognizes that societal and technological issues are becoming more and more interdependent. Leaders of government, non-profit and for-profit organizations are typically educated in non-engineering disciplines yet increasingly would benefit from a more technological grounding. The Liberal Arts and Engineering major, with its emphasis on problem solving, will prepare students not only for engineering but also for many other high-level careers, such as:

• Law
• Medicine and health care
• Energy policy
• Environmental policy
• Technology policy
• Finance
• Technology management
• International relations
• Public affairs and political service
• Performing arts, especially music and theatre
• Consulting

PROGRAM OUTCOMES
Graduates of the BA in Liberal Arts and Engineering major will have:

a) an ability to formulate and solve problems requiring knowledge of both technological and societal/humanistic needs and constraints
b) an ability to apply, as needed, the relevant fundamentals of mathematics, science, engineering, social sciences, and the humanities to solve such problems
c) an ability to use the techniques, skills, and modern tools necessary for professional practice
d) an ability to function on multi-disciplinary teams
e) an understanding of professional and ethical responsibility
f) an ability to communicate effectively in oral, written and visual modes
g) a recognition of the need for, and ability to engage in, lifelong learning, in response to the ever-increasing pace of change affecting societal needs and opportunities
h) the broad education necessary to understand the impact of professional solutions in a societal context, both locally and globally.

Minimum Distribution Requirements

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
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</thead>
<tbody>
<tr>
<td>1. Mathematics and Basic Sciences (Notes 1, 2)</td>
<td>3</td>
</tr>
<tr>
<td>2. Engineering Science and Design (Notes 3, 4, 5)</td>
<td>3</td>
</tr>
<tr>
<td>3. Humanities and Arts, Social Science, and Management Topics (Notes 6, 7)</td>
<td>3</td>
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<tr>
<td>4. MQP (Note 8)</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTES:
1. Mathematics must include differential and integral calculus and either probability or statistics.
2. All courses with prefixes BB, CH, PH, or GE count toward this requirement. Must include at least 1/3 Unit each of BB, CH, and PH.
3. Courses with prefixes BME, CE, CHE, CS, ECE, ES, and ME are eligible to count toward this requirement. These courses should be thematically related; students must gain approval of their program of study in this area from the Liberal Arts and Engineering Program Committee.
4. Must include either CS 1101 or CS 1102.
5. Must include at least one course in engineering design (such as ECE 2799 or ME 2300), plus at least two other courses with a significant laboratory component (a list of such courses will be maintained by the Liberal Arts and Engineering Program Committee).
6. Must include 2 Units of Humanities and Arts and Social Science. Courses with prefixes AR, HI, PY, RH, WR, IMGD, ECON, GOV, PSY, STS, and SD may be eligible to count toward this requirement. Courses must be selected from areas that strongly complement the practice of engineering, such as the history of technology, ethics, writing and visual rhetoric, economics, society-technology studies, and environmental studies. A list of such courses will be maintained by the Liberal Arts and Engineering Program Committee.
7. May include up to 1 Unit of Management. All courses with prefixes ACC, BUS, ETR, FIN, MKT, MIS, OIE, and OBC are eligible to count toward this requirement.
8. The MQP provides a capstone experience that builds on both the technical (Engineering Science and Design) and nontechnical (Humanities and Arts, Social Science, and Management Topics) components of the student's particular program. At least one advisor to the MQP must be a member of the Liberal Arts and Engineering Associated Faculty.

PROGRAMS OF STUDY AND RELEVANT COURSES
The Liberal Arts and Engineering program will offer considerable curricular flexibility to accommodate a wide range of student interests, but at the same time will require students to be intentional about developing a coherent program of study consistent with the program's objectives. Academic advising will play an important role in helping students plan their programs.

For more information and advice about the program, contact Prof. Lance Schachterle at les@wpi.edu.

The Engineering Science and Design component of the major (Distribution Requirement 2) must be approved by the Liberal Arts and Engineering Program Committee to ensure that it provides students with a focus in some area of engineering. Guidance and examples will be provided so that students know in advance what types of programs will be approved. The intent is to accommodate creative programs while avoiding programs that lack a coherent theme.
<table>
<thead>
<tr>
<th>Units</th>
<th>ECE Design</th>
<th>Energy and Environment</th>
<th>Engineering and Pre-Law</th>
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<td>15</td>
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**WPI General Education Institutional Requirements (5 Units)**

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<tr>
<th>1</th>
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<th>HU&amp;A of student's choice</th>
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<th>HI 2317</th>
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<tr>
<td>2</td>
<td>H&amp;A</td>
<td>HU&amp;A</td>
<td>HI 2324</td>
<td>EN/WR 2211</td>
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<td>H&amp;A</td>
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<td>HI 2334</td>
<td>EN/WR 3216</td>
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<tr>
<td>5</td>
<td>H&amp;A</td>
<td>HU&amp;A</td>
<td>HI 3331</td>
<td>RH 3112</td>
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<tr>
<td>6</td>
<td>H&amp;A</td>
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<td>7</td>
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<td>SS</td>
<td>PSY 1402</td>
<td>SOC 1202</td>
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<td>SS</td>
<td>SS/ID 2050</td>
<td>GOV 1301</td>
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<td>9</td>
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</table>

**Mathematics and Science (3 Units)**

| 16 | Math & Science | MA 1021 | MA 1021 | MA 1021 |
| 17 | Math & Science | MA 1022 | MA 1022 | MA 1022 |
| 18 | Math & Science | MA 1024 | MA 1024 | MA 1024 |
| 19 | Math & Science | MA 2051 | MA 2051 | MA 2051 |
| 20 | Math & Science | MA 2611 | MA 2611 | MA 2611 |
| 21 | Math & Science | CH 1010 | CH 1010 | CH 1010 |
| 22 | Math & Science | PH 1110 | CH 1020 | BB 1035 |
| 23 | Math & Science | PH 1120 | BB 1002 | PH 1110 |
| 24 | Math & Science | BB 1001 | PH 1110 | PH 1120 |

**Engineering Studies Cornerstone (3 Units)**

**Theme**

| 26 Engineering Sci/Des | ECE 2022 | ES 3003 | ES 1310 |
| 28 Engineering Sci/Des | ECE 2311 | ES 2501 | ES 2501 |
| 29 Engineering Sci/Des | ECE 2201 | ECE 2011 | ES 2502 |
| 30 Engineering Sci/Des | ECE 2801 | ECE 2111 | ES 2503 |
| 31 Engineering Sci/Des | ECE 2112 | ECE 3501 | ES 3003 |
| 32 Engineering Sci/Des | ECE 2799 (design) | ME 2300 (design) | ME 2300 (design) |
| 33 Engineering Sci/Des | CS 1101 | CS 1101 | CS 1101 |

**Liberal Arts Cornerstone (3 Units)**

**Theme**

| 34 Liberal Studies | PY 2714 Ethics in the Professions | PY 2717 Phil.&Environ. | GOV 1303 American Pub. Policy |
| 35 Liberal Studies | HI 1332 History of Technology | GOV 2311 Ev. Policy & Law | GOV 1310 Law, Courts, Politics |
| 36 Liberal Studies | HI 3331 Topics in Society/Technology Studies | PSY 2405 EV Problems & Human Cognition | GOV 2313 Intellectual Property Law |
| 37 Liberal Studies | STS 2208 Society-Technology Debate | GOV 2312 International EV Policy | GOV 2314 Cyberlaw and Policy |
| 38 Liberal Studies | GOV 2302 Science and Technology Policy | HI 3333 American Tech. Development | GOV 2304 Govt, Decision making and Admin Law |
| 39 Liberal Studies | STS 2209 Conflict and Cooperation in R&D Settings | GOV 2302 Science and Technology Policy | STS 2209 Conflict and Cooperation in R&D Settings |
| 40 Liberal Studies | OIE 2850 Engineering Economics | OIE 2850 Engineering Economics | BUS 2950 Bus Law & Ethics |
| 41 Liberal Studies | BUS 2950 Business Law and Ethics | BUS 2950 Business Law & Ethics | OIE 2850 Eng'g Economics |

**MQP – aimed at confluence of engineering and liberal arts cornerstones (1 Unit)**

| 43 MQP | MQP | MQP |
| 44 MQP | MQP | MQP |
| 45 MQP | MQP | MQP |
The Social and Humanistic Factors component (see Distribution Requirement 3 and Note 6) should consist of courses that complement engineering and technology to support the educational objectives of the program. The Program Committee will maintain and make available to students and advisors lists of current courses that are acceptable for credit toward this requirement.

MANAGEMENT

M. C. BANKS, HEAD
D. M. STRONG, DIRECTOR MIS PROGRAM

PROFESSORS: M. C. Banks, M. B. Elmes, A. Gerstenfeld, J. T. O’Connor, H. G. Vassallo
ASSISTANT PROFESSORS: S. Djamasi, F. Miller, K. Mukherjee, S. Taylor, B. Tulu, W. Zhao
VISITING FACULTY: J. Schaufeld

MISSION STATEMENT
The Department of Management at WPI is committed to providing education, research, and outreach that focus on:

• leading and managing technology-based organizations;
• integrating technology into the workplace; and
• creating new processes, products, services, and organizations based on technology.

We emphasize:

• innovative and project-based education that integrates the theory and the practice of management, and prepares students to assume positions of leadership in an increasingly global business environment;
• basic scholarship, while also valuing the scholarship of application and the scholarship of instruction; and
• interaction with the business community focused primarily on technological entrepreneurship.

COURSE AREAS

The Department of Management has recently changed its course prefixes from either MG or MG/IE to prefixes that more accurately reflect the course area. They are:

ACC  Accounting
BUS  Business
ETR  Entrepreneurship
FIN  Finance
MIS  Management Information Systems
MKT  Marketing
OIE  Operations & Industrial Engineering
OBC  Organizational Behavior and Change

MANAGEMENT (MG)

PROGRAM EDUCATIONAL OBJECTIVES

Objectives of the Management Major are:

To prepare students for management roles in technology-based organizations.

Through a flexible curriculum, to provide a solid, broad base of business knowledge and the written communication, oral presentation, decision-making, and leadership skills necessary to succeed in a technology-based environment.

To develop student abilities necessary for continued career growth including:

• the ability to integrate theory and practice;
• the ability to integrate technology and change into existing organizations;
• the ability to think critically and analytically, to define and solve business problems, work in teams, and think globally; and
• the ability to learn new skills in response to changing professional requirements.

Program Distribution Requirements for the Management Major

REQUIREMENTS (NOTE 1)  MINIMUM UNITS
1. Management Foundation (Note 2) 1 1/3
2. Mathematics (Note 3) 4/3
3. Basic Science 2/3
4. Management Major (Note 4) 6/3
5. Breadth Electives (Note 5) 3/3
6. Computer Science (Note 6) 1 1/3
7. MG MQP 3/3

NOTES:

1. Courses may not be counted more than once in meeting these distribution requirements. The total number of units taken in the Department of Management may not exceed 50% of the total number of units earned for the degree.

2. The Management Foundation must cover the foundation knowledge in the management functional areas, including at least 1/3 unit of financial accounting, managerial accounting, financial management, organizational science, deterministic management science, operations management, marketing management, information systems management, and business law and ethics. Microeconomics and Macroeconomics are required and also fulfill the WPI Social Science requirement.

3. Mathematics must include 2/3 units of calculus and 2/3 units of statistics.

4. Students selecting the Management Major must complete six courses from at most three (3) course clusters as specified on the department’s website (http://www.mgt.wpi.edu/Undergraduate/mgcur.html) or work with their academic advisor to create a custom MG Program that includes courses in the specified clusters and/or other areas of Humanities & Arts and Social Sciences & Policy Studies. Such custom programs must be approved by the advisor and the Department of Management’s Undergraduate Policy & Curriculum Committee.

5. Breadth Electives must include at least 1/3 unit from among the 3000- and 4000-level courses in the Department. The remaining 2/3 units specified in the requirement may be satisfied with courses from Mathematics, Basic Science, Computer Science, Social Science, or courses with any of the following prefixes: ACC, BUS, ETR, FIN, MIS, MKT, OBC, or OIE, but excluding courses FIN 1250 and OIE 2850.

6. A minimum of 1/3 unit of Computer Science (except CS 2022 and CS 3043). Either CS 1101 or CS 1102 is recommended.
MANAGEMENT ENGINEERING (MGE)

EDUCATIONAL PROGRAM OBJECTIVES
Objectives of the Management Engineering Major are:

To prepare students for management challenges in key areas that increasingly require proficiency in the technical aspects of business such as production and service operations.

To provide the knowledge and skills necessary to succeed professionally, including literacy in a technical field, a broad understanding of management issues, written communication, oral presentation, decision-making, and leadership skills required to create new and improved products, processes and control systems.

To develop student abilities necessary for continued career growth including:

- the ability to integrate theory and practice and to apply knowledge of technical issues with the foundations of management;
- the ability to integrate technology and change into existing organizations;
- the ability to think critically and analytically, to define and solve business problems, work in teams, and think globally; and
- the ability to learn new skills in response to changing professional requirements.

Program Distribution Requirements for the Management Engineering Major

<table>
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<tr>
<th>REQUIREMENTS (NOTE 1)</th>
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<tr>
<td>2. Mathematics (Note 3)</td>
<td>4/3</td>
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<tr>
<td>3. Basic Science</td>
<td>2/3</td>
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<tr>
<td>4. Management Engineering Major (Note 4)</td>
<td>6/3</td>
</tr>
<tr>
<td>5. Breadth Electives (Note 5)</td>
<td>3/3</td>
</tr>
<tr>
<td>6. Computer Science (Note 6)</td>
<td>1/3</td>
</tr>
<tr>
<td>7. MGE MQP</td>
<td>3/3</td>
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</tbody>
</table>

NOTES:
1. Courses may not be counted more than once in meeting these distribution requirements. The total number of units taken in the Department of Management may not exceed 50% of the total number of units earned for the degree.
2. The Management Foundation must cover the foundation knowledge in the management functional areas, including at least 1/3 unit of financial accounting, managerial accounting, financial management, organizational science, deterministic management science, operations management, marketing management, information systems management, and business law and ethics. Microeconomics and Macroeconomics are required and also fulfill the WPI Social Science requirement.
3. Mathematics must include 2/3 units of calculus and 2/3 units of statistics.
4. Students selecting the Management Engineering Major must complete six courses from one of the concentrations as specified on the Department’s website (http://www.mgt.wpi.edu/Undergraduate/mgtcur.html) or work with their academic advisor to create a custom MGE Program. Such custom programs must be approved by the Department of Management’s Undergraduate Policy & Curriculum Committee.
5. Breadth Electives must include at least 1/3 unit from among the 3000- and 4000-level courses in the Department. The remaining 2/3 units specified in the requirement may be satisfied with courses from Mathematics, Basic Science, Computer Science, Social Science, or courses with any of the following prefixes: ACC, BUS, ETR, FIN, MIS, MKT, OBC, or OIE, but excluding courses FIN 1250 and OIE 2850.
6. A minimum of 1/3 unit of Computer Science (except CS 2022 and CS 3043). Either CS 1101 or CS 1102 is recommended.

MANAGEMENT INFORMATION SYSTEMS (MIS)

EDUCATIONAL PROGRAM OBJECTIVES
The objectives of the Management Information Systems Major are:

To prepare students for positions involving the design and deployment of business applications using a wide variety of advanced information technologies, especially in high technology business, consulting, and service firms, in either start-up or established environments, and to prepare students for rapid advancement to project management and other management positions.

To provide the knowledge and skills consistent with the professionally accepted IS curriculum guidelines. Specifically, this includes providing knowledge and skills related to:

- business application development tools;
- database, web-based and networked applications;
- integrating IT into existing organizations through managing and leading systems analysis and design projects;
- communicating effectively via written and oral presentations.

To develop student abilities necessary for continued career growth including:

- the ability to integrate theory and practice and to apply knowledge of information technology issues with the foundations of management;
- the ability to integrate technology and change into existing organizations;
- the ability to think critically and analytically, to define and solve business problems, work in teams, and think globally; and
- the ability to learn new skills in response to changing professional requirements.

Program Distribution Requirements for the Management Information Systems Major

<table>
<thead>
<tr>
<th>REQUIREMENTS (NOTE 1)</th>
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<tr>
<td>1. Management Foundation (Note 2)</td>
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<tr>
<td>2. Mathematics (Note 3)</td>
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<tr>
<td>3. Basic Science</td>
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<td>4. Management Information Systems Major (Note 4)</td>
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<td>5. Breadth Electives (Note 5)</td>
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<td>6. Computer Science (Note 6)</td>
<td>1/3</td>
</tr>
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<td>7. MIS MQP</td>
<td>3/3</td>
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</tbody>
</table>

NOTES:
1. Courses may not be counted more than once in meeting these distribution requirements. The total number of units taken in the Department of Management may not exceed 50% of the total number of units earned for the degree.
2. The Management Foundation must cover the foundation knowledge in the management functional areas, including at least 1/3 unit of financial accounting, managerial accounting, financial management, organizational science, deterministic management science, operations management, marketing management, information systems management, and business law and ethics. Microeconomics and Macroeconomics are required and also fulfill the WPI Social Science requirement.
3. Mathematics must include 2/3 units of calculus and 2/3 units of statistics.
4. Students selecting the Management Information Systems Major must complete six courses as specified on the Department's website (http://www.mgt.wpi.edu/Undergraduate/mgtcur.html) or work with their academic advisor to create a custom MIS Program. Such custom programs must be approved by the advisor and the Department of Management’s Undergraduate Policy & Curriculum Committee.

5. Breadth Electives must include at least 1/3 unit from among the 3000- and 4000-level courses in the Department. The remaining 2/3 units specified in the requirement may be satisfied with courses from Mathematics, Basic Science, Computer Science, Social Science, or courses with any of the following prefixes: ACC, BUS, ETR, FIN, MIS, MKT, OBC, or OIE, but excluding courses FIN 1250 and OIE 2850.

6. A minimum of 1/3 unit of Computer Science (except CS 2022 and CS 3043). Either CS 1101 or CS 1102 is recommended.

ENTREPRENEURSHIP MINOR

All around the world people are starting their own new business ventures. With its strong heritage of invention and entrepreneurship among students and faculty members, WPI is committed to encouraging its students to consider that career path. Our dream is that our students will earn a minor in Entrepreneurship, which will provide them with some basic business skills and an understanding of what it takes to start a business, then they will create a new and exciting technology as their MQPs that they will then turn into a business upon graduation.

Related opportunities include the Robert H. Grant Invention Awards, the Henry Strage Innovation Awards, the CEI @ WPI ALL-OUT Business Plan Competition, the WPI Dinner with Entrepreneurs Series, the WPI chapter of CEO (Collegiate Entrepreneurs Organization), several conferences, many workshops, the monthly WPI Venture Forum meetings, a variety of speakers and other events related to entrepreneurship, and access to a wide network of entrepreneurs from around the U.S. and abroad.

The Minor in Entrepreneurship is available to all students except those majoring in MG, MGE, or MIS, who may take the courses as part of their major or as Breadth or Free Electives.

The minor requires the completion of two units of coursework as noted below.

1. Complete the following course:
   - OIE 2850 Engineering Economics

2. Complete two (2) from the following list:
   - ACC 1100 Financial Accounting
   - ACC 2101 Managerial Accounting
   - BUS 2950 Business Law & Ethics
   - OIE 2850 Engineering Economics
   - MKT 3600 Marketing Management
   - MIS 3700 Information Systems Management

3. Complete the following three courses, preferably in order:
   - ETR 3910 Identifying & Evaluating New Venture Opportunities
   - ETR 4930 Growing and Managing New Ventures
   - ETR 3920 Planning & Launching New Ventures

   As noted above, students majoring in MG, MGE, or MIS may not minor in Entrepreneurship.

   For general policy on the Minor, see the description on page 12.

MANAGEMENT MINOR

Everyone needs management skills. If engineers, scientists, and others hope to advance in their careers, they must learn how to lead projects and manage groups. The Management Minor offers students (other than MG, MGE, or MIS majors, who may take the courses as part of their major or as Breadth or Free Electives, as appropriate) the opportunity to learn some of the theory and practice of managing in organizations with material on management concepts and practices commonly encountered in the business world. This program will help students make a transition to the business world and will provide basic skills for operating effectively in business organizations.

To complete the Management Minor, a student must complete two units of work in the Management Area, typically through course work with the following distribution:

1. One course from the Social Science Economics area.
   - Any course with course designation ECON#1## will qualify.

2. ACC 1100, Financial Accounting

3. OBC 2300, Organizational Science I

4. Either MKT 3600, Marketing Management, or MKT 3651, Industrial Marketing

5. Select one (1) from the following group:
   - a. ACC 2101, Managerial Accounting
   - b. FIN 2200, Financial Management
   - c. OBC 3351, Organizational Science – Management of Change
   - d. OIE 3400, Production System Design
   - e. MKT 3640, Management of Process and Product Innovation
   - f. MIS 3700, Information Systems Management
   - g. OBC 4365, Leadership in Groups and Organizations

6. Capstone Experience ETR 4930, Growing and Managing New Ventures

As noted above, students majoring in MG, MGE, or MIS may not minor in Management.

For general policy on the Minor, see the description on page 12.

MIS MINOR

Information technology has been the driving force behind the new way of doing business. It has enabled companies to make tremendous strides in productivity, it has opened new markets and new channels, and it has created new product and service opportunities. While one part of the information revolution has been advances in hardware, and another has been advances in software, a third major advance has been in the systems-side of information, or how information is organized and used to make effective decisions. That is Management Information Systems (MIS). The Minor in MIS offers students (other than MG, MGE, or MIS majors, who may take the courses as part of their major or as Breadth or Free Electives, as appropriate) the opportunity to broaden their disciplinary program with material and skills widely useful in the business world. This program will help students to broaden their exposure to information technology and its use in business and industry.
To complete the Management Information Systems Minor, a student must complete two units of work with the following distribution:

1. One course from the group of courses:
   - BUS 1900 Introduction to Business in an International Environment OR
   - ACC 1100 Financial Accounting OR
   - ACC 2101 Management Accounting OR
   - OBC 2300 Organizational Science

2. Two courses, or their equivalents, from the following list:
   - CS 1101 Introduction to Program Design OR
   - CS 1102 Accelerated Introduction to Program Design OR
   - CS 2118 Object-Oriented Design Concepts for Business Applications OR
   - CS 2301 Systems Programming for Non-Majors OR
   - CS 2303 Systems Programming Concepts

3. Two courses from the group of courses:
   - MIS 3700 Information Systems Management
   - MIS 3720 Management of Data
   - MIS 3740 Organizational Application of Telecommunications

4. Capstone Experience
   - MIS 4720: Systems Analysis and Design
   - Course MIS 4720 is a project-oriented course designed to prepare MIS students and minors for actual information systems design work in business and industry. The course builds and uses MIS concepts for the sound and efficient design of information systems.

   Students majoring in MG, MGE, or MIS may not take the MIS Minor.

For general policy on the Minor, see the description on page 12.

ORGANIZATIONAL LEADERSHIP MINOR

One of the critical elements for any person who hopes to succeed in a formal organization is leadership. While some people come by their organizational leadership abilities instinctively or by learning from others at an early age, many others come late to their leadership talents and still others never realize their leadership abilities. It is the purpose of the Department of Management's Organizational Leadership minor to provide students with the theoretical underpinnings of leadership and, in keeping with a WPI education, the knowledge of how that theory applies to practice. Thus, through this minor students will be able to understand and apply leadership theories to their lives and, in the process, make themselves more marketable upon graduation.

The minor in Organizational Leadership consists of three primary components. These components are a choice of Management courses, a choice among three Social Science & Policy Studies courses, and a capstone course in Leadership.

1. Select four of the following:
   - BUS 1900 Introduction to Business in an International Environment
   - OBC 2300 Organizational Science - Foundation
   - BUS 2950 Business Law & Ethics
   - OBC 3351 Organizational Science - Management of Change
   - OBC 4364 Human Resource Management

2. Select one of the following:
   - PSY 1401 Cognitive Psychology
   - PSY 1402 Social Psychology
   - PSY 2406 Cross-Cultural Psychology: Human Behavior in Global Perspective

3. Required Capstone Experience
   - OBC 4365 Leadership in Groups and Organizations
   - Note: The minor in Organizational Leadership may not be taken by students majoring in MG, MGE, or MIS. These students may take the courses as part of their major or as Breadth or Free Electives, as appropriate.

   For general policy on the Minor, see the description on page 12.

MANUFACTURING ENGINEERING

DIRECTOR: R. D. SISSON
ASSOCIATE DIRECTOR: Y. RONG
ASSOCIATE PROFESSORS: M. Fofana, S. Johnson, F. Noonan, A. Zeng
RESEARCH PROFESSOR: R. Katz
LECTURERS: P. D. Colmoir, K. Stafford

MISSION STATEMENT

The mission of WPI’s Manufacturing Engineering Program: Provide an outstanding Manufacturing Engineering education that realizes students’ visions, fulfills industry needs, and produces future leaders.

PROGRAM EDUCATIONAL OBJECTIVES

- Graduates should have the knowledge and skills to design and enact solutions for complex, dynamic manufacturing engineering problems faced by industry and society, using current concepts and technology
- Graduates should be able to communicate effectively, both orally and in writing, using electronic tools and graphical representations
- Graduates should be able to serve and lead the organizations that employ them, with good interpersonal and teamwork skills and with an understanding of professional ethical responsibility, and national and global contemporary issues

Program Distribution Requirements for the Manufacturing Engineering Major

The normal period of residency at WPI is 16 terms. In addition to WPI requirements applicable to all students, students wishing to receive the degree designated “Manufacturing Engineering” must satisfy certain distribution requirements:

REQUIREMENTS

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics and Basic Science (Notes 1,2)</td>
<td>4</td>
</tr>
<tr>
<td>2. Engineering Science and Design (including the MQP) (Note 3,4)</td>
<td>6</td>
</tr>
</tbody>
</table>

NOTES:

1. Mathematics must include differential and integral calculus and differential equations.
2. Science must include both chemistry and physics with a minimum of two courses in either.
3. At least one unit from each of the following areas is required:
   A. Materials and Processes
   B. Product Engineering
   C. Computer Control and Manufacturing Systems
   D. Production Systems Engineering
4. Must include 1/3 unit of Capstone Design Experience.
**MANUFACTURING ENGINEERING PROGRAM CHART**

### BACKGROUND

<table>
<thead>
<tr>
<th>4 Units</th>
<th>2/3 Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MATHEMATICS</strong></td>
<td><strong>SCIENCE</strong></td>
</tr>
<tr>
<td>*MA 1021</td>
<td>CH 1010</td>
</tr>
<tr>
<td>*MA 1022</td>
<td>CH 1020</td>
</tr>
<tr>
<td>*MA 1023</td>
<td>PH 1100</td>
</tr>
<tr>
<td>*MA 1024</td>
<td>PH 1120</td>
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<tr>
<td>*MA 2051</td>
<td>PH 1130</td>
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<tr>
<td>MA 2071</td>
<td>PH 1140</td>
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<td>MA 2611</td>
<td>BB 1001</td>
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<td>MA 2612</td>
<td>BB 1002</td>
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<td>MA 2621</td>
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<td>MA 3831</td>
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<tr>
<td>MA 3832</td>
<td></td>
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<tr>
<td>MA 4631</td>
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</tr>
</tbody>
</table>

**Mathematics requirements include differential and integral calculus and ordinary differential equations. Additional work is strongly encouraged in one or more of the subjects of probability and statistics, linear algebra, and numerical analysis.**

**Science requirements include chemistry and physics with at least a two course sequence in either.**

### MAJOR QUALIFYING PROJECT (MQP)

1 Unit

**FREE ELECTIVE**

Refer to catalog

### INTERACTIVE QUALIFYING PROJECT (IQP)

see page 17

### SOCIAL SCIENCE

see page 159

### HUMANITIES & ARTS

see page 128

### PHYSICAL EDUCATION

see page 155

### BACKGROUND

**6 Units** (Divided approximately 2:1 between Engineering Science: Design)

#### 1 Unit

**MATERIALS & PROCESSES**

<table>
<thead>
<tr>
<th>Electives</th>
<th>One unit per area required</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES 2001</td>
<td></td>
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<tr>
<td>ME 1800</td>
<td></td>
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<tr>
<td>ME 2820</td>
<td></td>
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<td>ME 4821</td>
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<tr>
<td>ME 3023</td>
<td>ES 1310</td>
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<tr>
<td>ME 3811</td>
<td>ES 3323</td>
</tr>
<tr>
<td>ME 4813</td>
<td>ES 3310</td>
</tr>
<tr>
<td>ME/BME 4814</td>
<td>ME 3311</td>
</tr>
<tr>
<td>ME 4816</td>
<td>ME 3321</td>
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<tr>
<td>ME 4822</td>
<td>ME 4320</td>
</tr>
<tr>
<td>MFE 520</td>
<td>MFE 540</td>
</tr>
</tbody>
</table>

#### 1 Unit

**PRODUCT ENGINEERING AND TOOL DESIGN**

<table>
<thead>
<tr>
<th>Electives</th>
<th>One unit Emphasizing Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES 2501</td>
<td></td>
</tr>
<tr>
<td>ES 2502</td>
<td></td>
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<tr>
<td>ES 2503</td>
<td></td>
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<tr>
<td>ME 3320</td>
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</tbody>
</table>

#### 1 Unit

**COMPUTER CONTROL & MANUFACTURING SYSTEMS**

<table>
<thead>
<tr>
<th>Electives</th>
<th>One unit Emphasizing Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECE 3601</td>
<td></td>
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<tr>
<td>ES 3011</td>
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<tr>
<td>ME 3820</td>
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<tr>
<td>ME 4815</td>
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<tr>
<td>ECE 2011</td>
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<tr>
<td>CS 2301</td>
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<td>CS 3013</td>
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<td>CS 3431</td>
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<tr>
<td>CS 4032/MA 3257</td>
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<tr>
<td>CS 4033/MA 3457</td>
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<tr>
<td>MFE 510</td>
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<tr>
<td>MFE 530</td>
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</tbody>
</table>

#### 1 Unit

**PRODUCTION SYSTEMS ENGINEERING**

<table>
<thead>
<tr>
<th>Electives</th>
<th>One unit Emphasizing Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>OIE 2850</td>
<td></td>
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<tr>
<td>OIE 3400</td>
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<tr>
<td>OIE 3401</td>
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<td>OIE 2500</td>
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<td>OIE 3405</td>
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<td>OIE 3460</td>
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</tr>
<tr>
<td>OIE 3501</td>
<td></td>
</tr>
<tr>
<td>OIE 4460</td>
<td></td>
</tr>
</tbody>
</table>
MANUFACTURING ENGINEERING MINOR

A minor in Manufacturing Engineering gives students from a variety of majors the opportunity to strengthen their academic preparation and attractiveness to industry, while better preparing them to solve many of the problems that will challenge them in their careers. Most engineers are involved directly or indirectly with manufacturing or manufacturing principles. Manufacturing expertise is essential to all industrialized, developing and even post industrialized societies. The objective of the minor in manufacturing will be to give the students a solid understanding of the principles of production, processing, manufacturability, and quality that can be applied to a wide variety of products, including non-traditional products, such as software, service and information.

The minor requires the completion of 2 units of work as follows.

I. 1 unit of required course work selected from the following list:
   ME 1800 Material Selection and Manufacturing Processes
   ME 2820 Materials Processing
   ME 3820 Computer-Aided Manufacturing
   ES 3011 Control Engineering I

II. 2/3 unit of electives, selected from the following list of courses:
    any of the courses above, in I., can count if the other three are completed.
    CS 4032/MA 3257 Numerical Methods for Linear and Nonlinear Systems
    CS 4341 Introduction to Artificial Intelligence
    ES 3323 Advanced Computer Aided Design
    ME 3310 Kinematics of Mechanisms
    ME 4530 Computational Methods in Mechanical Engineering
    ME/BE 4815 Industrial Robotics
    ME 4821 Chemistry, Properties and Processing of Plastic
    OIE 3400 Production System Design
    OIE 3420 Quality Planning, Design and Control
    MFE 510 Control and Monitoring of Manufacturing Processes
    MFE 511 Application of Industrial Robotics
    MFE 520 Design and Analysis of Manufacturing Processes
    MFE 530 Computer Integrated Manufacturing
    MFE 540 Design for Manufacturability

III. 1/3 unit of capstone experience:
    ME 4815 Industrial Robotics
    ME 598 Independent Study Project (this must be approved by the MFE minor program committee)
    MFE 510 Control and Monitoring of Manufacturing Processes
    MFE 511 Application of Industrial Robotics
    MFE 520 Design and Analysis of Manufacturing processes
    MFE 530 Computer Integrated Manufacturing
    MFE 540 Design for Manufacturability

MATERIALS ENGINEERING

Courses and programs of study in materials engineering are included in the Mechanical Engineering Department (page 88). For advisory information, consult that section of the Undergraduate Catalog or members of the materials section of Mechanical Engineering.

MINOR IN MATERIALS

Material properties, material processing issues, or material costs are the limiting factor in the design or performance of almost all systems around us. Engineers, scientists, and managers in all technological sectors often must make material selection decisions based on a variety of considerations, including properties, performance, environmental impact, and cost. A Minor in Materials, feasible within a 15 unit program of study, will benefit students who wish to enhance their disciplinary major with an additional degree designation in the area of materials.

REQUIREMENTS FOR THE MATERIALS MINOR:

The minor requires the completion of 2 units of work as described below:

1. ES 2001 Introduction to Material Science (1/3 unit)
2. 1-1/3 units of electives, selected from the following list of courses:
    CE 3026 Materials of Construction
    CH 3410 Principles of Inorganic Chemistry
    CH 2310 Organic Chemistry I
    CH 2320 Organic Chemistry II
    CH 2330 Organic Chemistry III
    CH 4330 Organic Synthesis
    CH 4550 Polymer Chemistry
    CHE 3601 Chemical Materials Engineering
    ECE 3901 Semiconductor Devices
    ME 2820 Materials Processing
    ME 3801 Experimental Methods in Materials Science & Engineering
    ME 4718 Advanced Materials with Aerospace Applications
    ME 4810 Automotive Materials and Process Design
    ME 4813 Ceramics and Glasses for Engineering Applications
    ME/BME 4814 Biomaterials
    ME 4821 Plastics
    ME 4832 Corrosion and Corrosion Control
    ME 4840 Physical Metallurgy
    ME 4860 Food Engineering
    ME 4875 Introduction to Nanomaterials and Nanotechnology
    PH 3502 Solid State Physics

Students who are able to design their undergraduate program of study such that they have sufficient preparation may also use the following graduate courses toward a Materials Minor: all MTE graduate courses; CHE 508, Catalysis and Surface Science of Materials; CHE 510, Particulate Systems.
3. Capstone Experience (1/3 unit)
   The capstone experience requirement for the Minor in Materials must be satisfied by an upper level course or IS/P activity that integrates and synthesizes material processing, structure, and property relationships as they affect performance.
   
i) Courses that satisfy the capstone experience requirement currently include ME 4810, ME 4813, ME 4814, and ME 4821. Other courses must be approved in advance by the Program Committee for the Minor in Materials.
   
ii) Students may satisfy the capstone experience requirement by completing a 1/3 unit IS/P that receives prior approval from the Program Committee for the Minor in Materials. The IS/P may, for example, take the form of a laboratory experience or may augment the MQP or IQP, considering in depth the materials issues associated with the project topic (see Note d). An IS/P related to the MQP must be distinct from the core 1 unit of the MQP and in most cases would be advised by a faculty member other than the MQP advisor.

NOTES:
   
a. In accordance with the Institute-wide policy on Minors, academic activities used in satisfying the regular degree requirements may be double-counted toward meeting all but one unit of the Minor requirements (see page 12).
   
b. Physics IS/P courses in Superconductors, Photonics, and Lasers may also be counted toward the Materials Minor. In addition, other new or experimental course offerings in the materials area may be approved by the Materials Minor Program Review Committee.
   
c. Examples: An ECE major designing an integrated circuit for her MQP might conduct a separate analysis of the materials issues related to heat management in the device as the capstone experience for the Minor in Materials; a ME major specifying a gear in a design MQP might conduct a separate analysis of the material processing, structure, and property issues affecting fatigue life of the gear.
   
d. In accordance with the Institute-wide policy on Minors, the Major Qualifying Project (MQP) cannot be counted toward activity for a Minor. Therefore, a ME, CHE, or any other major whose MQP is judged to be predominantly in the materials area by the Program Review Committee may not count an extra 1/3 unit augmentation of their MQP as their capstone experience in the Minor.
   
e. The following faculty serve as the Program Review Committee for the Minor in Materials and will serve as Minor Advisors: Richard Sisson (ME), Chrys Demetry (ME), Tahar El-Korchi (CEE).

MATHERNICAL SCIENCES

B. VERNESCU, HEAD; S. WEEKES, ASSOCIATE HEAD


ASSISTANT PROFESSORS: R. Kim, H. Sayit, D. Volkov, J. Wilbur

VISITING FACULTY: M. Blais, C. Burgos, V. Hrynkv, C. Lee, J. Mosamune, V. Yakovlev

ACADEMIC STAFF: J. Abraham, J. Goulet

MISSION STATEMENT

Recognizing the vital role of the mathematical sciences in today’s society, the Mathematical Sciences Department provides leading-edge programs in education, research, and professional training in applied and computational mathematics and statistics. These programs are enhanced and distinguished by project-oriented education and collaborative involvement with industry, national research centers, and the international academic community.

PROGRAM EDUCATIONAL OBJECTIVES

The department’s major programs provide students with preparation for effective and successful professional careers in the mathematical sciences, whether in traditional academic pursuits or in the many new career areas available in today’s technologically sophisticated, globally interdependent society. Through course work, students acquire a firm grounding in fundamental mathematics and selected areas of emphasis. Projects, which often involve interdisciplinary and industrial applications, offer further opportunities to gain mathematical depth and to develop skills in problem-solving, communication, teamwork, and self-directed learning, together with an understanding of the role of the mathematical sciences in the contemporary world.

PROGRAM OUTCOMES

We expect graduates to:

1. have a solid knowledge of a broad range of mathematical principles and techniques and the ability to apply them.
2. be able to read, write, and communicate mathematics inside and outside the discipline.
3. have the ability to formulate mathematical statements and prove or disprove them.
4. be able to formulate and investigate mathematical questions and conjectures.
5. understand fundamental axiom systems and essential definitions and theorems.
6. be able to formulate and analyze mathematical or statistical models.
7. have the ability to apply appropriate computational technology to analyze and solve mathematical problems.
8. be able to learn independently and as part of a team, and to demonstrate a depth of knowledge in at least one area of the mathematical sciences.
The Department of Mathematical Sciences at WPI offers:

i) the Bachelor of Science degree in Mathematical Sciences;

ii) the Bachelor of Science degree in Actuarial Mathematics;

iii) a Minor in Mathematics;

iv) a Minor in Statistics;


**Program Distribution Requirements for the Mathematical Sciences Major**

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students, completion of a minimum of 10 units of study is required as follows:

### REQUIREMENTS

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics including MQP (See notes 1–4).</td>
<td>7</td>
</tr>
<tr>
<td>2. Courses from other departments that are related to the student's mathematical program. At least 2/3 unit in computer science must be included; the remaining courses are to be selected from science, engineering, computer science or management (except MG 1250) (see Note 5).</td>
<td>2</td>
</tr>
<tr>
<td>3. Additional courses or independent studies (except MS, PE courses, and other degree requirements) from any area.</td>
<td>1</td>
</tr>
</tbody>
</table>

### NOTES:

1. Must include MA 3831-3832, or their equivalents, at least one of MA 3257, MA 3457, or equivalent, and at least one of MA 3823, MA 3825, or equivalent.

2. Must include at least three of the following: MA 2073, MA 2271, MA 2273, MA 2431, MA 2631, or their equivalents.

3. At least 7/3 units must consist of MA courses at the 3000 level or above.

4. May not include both MA 2631 and MA 2621.

5. May not include both CS 3043 and CS 2022.

### PROGRAMS IN MATHEMATICAL SCIENCES

**PROJECTS**

Some of the most active career directions in the mathematical sciences are reflected in the MQP areas around which the department’s offerings are organized: Algebraic and Discrete Mathematics, Computational and Applied Analysis, Operations Research, and Probability and Statistics. As early as practical, and certainly no later than the sophomore year, the mathematical sciences major should begin exploring these different areas. The transition courses, MA 2073, 2271, 2273, 2431, and 2631, are specifically designed to introduce the four MQP areas while preparing the student for advanced courses and the MQP. Students should talk to faculty in the student's area of interest to develop and select an MQP and MQP advisor.

While most students choose MQPs in one of the four areas mentioned above, it is possible to design an MQP that does not fit into any one area. In such cases, students will want to take special care to plan their programs carefully with their advisors so that sufficient background is obtained before beginning to do research. Independent studies are a good way for students to learn topics that are not taught in regularly-scheduled courses. Interested students should approach faculty with requests for independent studies.

Through the Center for Industrial Mathematics and Statistics (CIMS), students can use their mathematics and statistics training to work on real-world problems that come from sponsors in industry and finance. More information about industrial MQPs and projects can be found at [http://www.wpi.edu/~CIMS](http://www.wpi.edu/~CIMS).

In what follows, you will find for each MQP area:

- A brief description of the area including the kinds of challenges likely to be encountered by MQP students and mathematical scientists working there.
- Courses of interest.

**ALGEBRAIC AND DISCRETE MATHEMATICS**

Algebraic and discrete mathematics is recognized as an increasingly important and vital area of mathematics. Many of the fundamental ideas of discrete mathematics play an important role in formulating and solving problems in a variety of fields ranging from ecology to computer science. For instance, graph theory has been used to study competition of species in ecosystems, to schedule traffic lights at an intersection, and to synchronize parallel processors in a computer. Coding theory has been applied to problems from the private and public sectors where encoding and decoding information securely is the goal. In turn, the problems to which discrete mathematics is applied often yield new and interesting mathematical questions. The goal of a project in discrete mathematics would be to experience this interaction between theory and application. To begin, a typical project team would assess the current state of a problem and the theory that is relevant. Once this is done, the project team’s objective would be to make a contribution to solving the problem by developing new mathematical results.

In working in discrete mathematics, one may be writing algorithms, using the computer as a modeling tool, and using the computer to test conjectures. It is important that a student interested in this area have some computer proficiency. Depending on the project, an understanding of algorithm analysis and computational complexity may be helpful.

### Courses of Interest

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA 2271</td>
<td>Graph Theory</td>
</tr>
<tr>
<td>MA 2273</td>
<td>Combinatorics</td>
</tr>
<tr>
<td>MA 3231</td>
<td>Linear Programming</td>
</tr>
<tr>
<td>MA 3232</td>
<td>Discrete Optimization</td>
</tr>
<tr>
<td>MA 3823</td>
<td>Group Theory</td>
</tr>
<tr>
<td>MA 3825</td>
<td>Rings and Fields</td>
</tr>
<tr>
<td>MA 4891</td>
<td>Topics in Mathematics (when appropriate)</td>
</tr>
<tr>
<td>CS 2301</td>
<td>Systems Programming for Non-Majors</td>
</tr>
<tr>
<td>CS 4120</td>
<td>Analysis of Algorithms</td>
</tr>
<tr>
<td>CS 4123</td>
<td>Theory of Computation</td>
</tr>
</tbody>
</table>

**COMPUTATIONAL AND APPLIED ANALYSIS**

This area of mathematics concerns the modeling and analysis of continuous physical or biological processes that occur frequently in science and engineering. Students interested in this area should have a solid background in analysis which includes the ability to analyze ordinary and partial differential equations through both analytical and computational means.

In most circumstances, an applied mathematician does not work alone but is part of a team consisting of scientists and engineers. The mathematician’s responsibility is to formulate a mathematical model from the problem, analyze the model, and then interpret the results in light of the experimental evidence.
It is, therefore, important for students to have some experience in mathematical modeling and secure a background in one branch of science or engineering through a carefully planned sequence of courses outside of the department. With the increase in computational power, many models previously too complicated to be solvable, can now be solved numerically. It is, therefore, recommended that students acquire enough computer proficiency to take advantage of this. Computational skill is growing in importance and should be a part of every applied mathematician’s training. Students may learn these skills through various numerical analysis courses offered by the department. An MQP in this area will generally involve the modeling of a real-life problem, analyzing it, and solving it numerically.

Courses of Interest
MA 2251  Vector and Tensor Calculus
MA 2431  Mathematical Modeling with Ordinary Differential Equations
MA 3231  Linear Programming
MA 3257  Numerical Methods for Linear and Nonlinear Systems
MA 3457  Numerical Methods for Calculus and Differential Equations
MA 3471  Advanced Ordinary Differential Equations
MA 3475  Calculus of Variations
MA 4235  Mathematical Optimization
MA 4291  Applicable Complex Variables
MA 4411  Numerical Analysis of Differential Equations
MA 4451  Boundary Value Problems
MA 4473  Partial Differential Equations

OPERATIONS RESEARCH
Operations research is an area of mathematics which seeks to solve complex problems that arise in conducting and coordinating the operations of modern industry and government. Typically, operations research looks for the best or optimal solutions to a given problem. Problems within the scope of operations research methods are as diverse as finding the lowest cost school bus routing that still satisfies racial guidelines, deciding whether to build a small plant or a large plant when...

**UNIVERSITY REQUIREMENTS**

<table>
<thead>
<tr>
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**FOUNDATION COURSES**

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**INTRODUCTORY COURSES**

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<th>COURSE</th>
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<tbody>
<tr>
<td>Computer Science Courses</td>
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* Category II courses, offered in alternating years.
demand is uncertain, or determining how best to allocate timesharing access in a computer network.

Typically, these problems are solved by creating and then analyzing a mathematical model to determine an optimal strategy for the organization to follow. Often the problem requires a statistical model, and nearly always the analysis - whether optimizing through a set of equations or simulating the behavior of a process - involves the use of a computer. Finally, operations researchers must be able to interpret and apply the results of their analyses in an appropriate manner.

In addition to a solid background in calculus, probability and statistics, and the various operations research areas, prospective operations researchers should be familiar with computer programming and managerial techniques.

**Courses of Interest**

MA 2271  Graph Theory  
MA 2273  Combinatorics  
MA 3231  Linear Programming  
MA 3233  Discrete Optimization  
MA 3627  Applied Statistics III  
MA 3631  Mathematical Statistics  
MA 4235  Mathematical Optimization  
MA 4237  Probabilistic Methods in Operations Research  
MA 4631  Probability and Mathematical Statistics I  
MA 4632  Probability and Mathematical Statistics II  
OIE 2500  Management Science I: Deterministic Decision Models  
OIE 3460  Simulation Modeling and Analysis  
OIE 3501  Management Science II: Risk Analysis

**PROBABILITY AND STATISTICS**

In many areas of endeavor, decisions must be made using information which is known only partially or has a degree of uncertainty attached to it. One of the major tasks of the statistician is to provide effective strategies for obtaining the relevant information and for making decisions based on it. Probabilists and statisticians are also deeply involved in stochastic modeling - the development and application of mathematical models of random phenomena. Applications to such areas as medicine, engineering, and finance abound.

Students interested in becoming probabilists or mathematical statisticians should consider additional study in graduate school. While graduate study is an option for students whose goals are to be applied statisticians, there are also career opportunities in business, industry, and government for holders of a Bachelor's degree. More information about careers in statistics can be found at the American Statistical Association's web site http://www.amstat.org/careers.

Students planning on graduate studies in this area would be well advised to consider, in addition to the courses of interest listed below, additional independent study or PQP work in probability and statistics, or some of the department's statistics graduate offerings.

**Courses of Interest**

MA 2611  Applied Statistics I  
MA 2612  Applied Statistics II  
MA 2631  Probability  
MA 3627  Applied Statistics III  
MA 3631  Mathematical Statistics  
MA 4237  Probabilistic Methods in Operations Research  
MA 4631  Probability and Mathematical Statistics I  
MA 4632  Probability and Mathematical Statistics II

**PROGRAM IN ACTUARIAL MATHEMATICS**

Actuaries provide financial evaluations of risk that help professionals in the insurance and finance industries, and many in large corporations and government agencies make strategic management decisions. Fellowship in the Society of Actuaries or the Casualty Actuarial Society – achieved by passing a series of examinations – is the most widely accepted standard of professional qualification to practice as an actuary.

WPI’s program enables students to take the first steps toward preparing for these exams and introduces these majors to the fundamentals of business and economics.

**PROJECTS**

Off-campus qualifying projects are regularly done in collaboration with insurance companies, and have in the past been sponsored by Aetna, Allmerica Financial, Blue Cross Blue Shield of Massachusetts, John Hancock Mutual Insurance, Premier Insurance, and Travelers Property Casualty. Visit http://www.wpi.edu/~CIMS. These projects give real-world experience of the actuarial field by having students involved in solving problems faced by professional actuaries. Instead of choosing a project already posed by a company/advisor team, students may instead seek out industry-sponsored projects on their own (often through internship connections) and propose them to a potential faculty advisor. Alternatively, students may choose to complete any other project in mathematics.

**Program Distribution Requirements for the Actuarial Mathematics Major**

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students, completion of a minimum of 10 units of study is required as follows:

**REQUIREMENTS**  
**MINIMUM UNITS**

1. Mathematics (including MQP) (See notes 1-6).  
2. Management (See note 7).  
3. Additional courses or independent studies (except MS, PE courses, and other degree requirements) from any area (See note 8).  

**NOTES:**

1. Must include MA 3831 and MA 3832, or their equivalents, at least one of MA 3257, MA 3457, or equivalent, and at least one of MA 3631, MA 4632, or equivalent.
2. Must include two of the following: MA 2073, MA 2271, MA 2273, MA 2431, MA 2631, or their equivalents.
3. Must include three of the following: MA 3211, MA 3212, MA 4213, MA 4214, or their equivalents.
4. May not include independent studies directed toward Society of Actuaries exams.
5. May not include either MA 2201 or MA 2210.
6. May not include both MA 2631 and MA 2621.
7. Must include ACC 2101 and FIN 2200 or their equivalents.
8. Must include 2/3 units of computer science.

Students interested in pursuing a degree in Actuarial Mathematics should contact Professor Abraham, the Coordinator of the Actuarial Mathematics Program, as soon as possible.
# Actuarial Mathematics Major Program Chart

## University Requirements

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<thead>
<tr>
<th>Requirement</th>
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## Introductory Courses

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## Core Courses

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## Actuarial Courses

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## Other MA Courses to Attain Total of 6 Units:

### Actuarial Math

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### Analysis

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### Algebra

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### Statistics/Probability

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## Other Requirements

### Computer Science

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* Category II courses, offered in alternating years.
STATISTICS MINOR

Statistical methods are widely used in science, engineering, business, and industry. The Statistics Minor is appropriate for all WPI students with interests in experimental design, data analysis, or statistical modeling. The minor is designed to enable a student to properly design studies and analyze the resulting data, and to evaluate statistical methods used in their field of study. Students should discuss course selections for the minor in advance with a statistics faculty member, who serves as the Minor Advisor. The student must complete the Statistics Minor Program Planning and Approval Form, and have it signed by the Minor Advisor. Students are encouraged to do this as early as possible, but it must be done prior to starting the Capstone. The following requirements must be satisfied.

1. At least 5/3 units of coursework, which must be drawn from the following lists of Foundation and Upper-Level Courses, and which must include successful completion of at least 2/3 units from each list:

   Courses for Statistics Minor (5/3 Unit Required)
   Foundation Courses (2/3 Unit Required)
   - MA 2073 Matrices and Linear Algebra II
   - MA 2611 Applied Statistics I
   - MA 2612 Applied Statistics II
   - MA 2631 Probability, or
   - MA 2621 Probability for Applications

   Upper-Level Courses (2/3 Unit Required)
   - MA 3627 Applied Statistics III
   - MA 3631 Mathematical Statistics
   - MA 4213 Risk Theory
   - MA 4214 Survival Models
   - MA 4237 Probabilistic Methods in Operations Research
   - MA 4631 Probability and Mathematical Statistics I
   - MA 4632 Probability and Mathematical Statistics II
   Any statistics graduate course:
   - MA 509 or any course numbered MA 540 through MA 559

2. The final 1/3 unit Capstone Experience: The capstone experience may be satisfied by certain 3000-level, 4000-level or graduate courses offered by the department or by a suitable independent study with a Statistics minor faculty member. The Capstone must be approved in advance by the instructor. This is done by having the Capstone instructor sign the Statistics Minor Program Approval Form. After completion of the Capstone Experience, the Statistics Minor Program Planning and Approval Form is submitted to the Mathematical Sciences Program Review Chair for final approval.

For information about the Statistics Minor, see any of the statistics faculty: Professors Joseph D. Petruccelli, Balgobin Nandram, or Jayson D. Wilbur.

MATHEMATICS MINOR

The Minor in Mathematics consists of successful completion of at least 2 units of academic activities in mathematical sciences. Students should discuss course selections for the minor in advance with a member of the mathematical sciences faculty who will serve as the Minor Advisor. The student must complete the Mathematics Minor Program Planning and Approval Form and have it signed by the Minor Advisor. Students are encouraged to do this as early as possible, but it must be done prior to starting the Capstone. The following requirements must be satisfied.

1. At least 5/3 units must be coursework in the Mathematical Sciences Department at the 2000 level or above, of which at least 2/3 units must be upper-level courses, i.e. 3000-level, 4000-level, or graduate mathematics courses. Courses selected at the 2000 level, if any, must include at least one of the following courses:
   - MA 2073 Matrices and Linear Algebra II
   - MA 2251 Vector and Tensor Calculus
   - MA 2271 Graph Theory
   - MA 2273 Combinatorics
   - MA 2431 Mathematical Modeling with Ordinary Differential Equations
   - MA 2631 Probability

2. The final 1/3 unit Capstone Experience: The experience may be satisfied by certain 3000-level, 4000-level or graduate courses offered by the department or by a suitable independent study with a Mathematical Sciences faculty member. The Capstone must be approved in advance by the instructor. This is done by having the Capstone instructor sign the Mathematics Minor Planning and Approval Form. After completion of the Capstone Experience, the Mathematics Minor Program Planning and Approval Form is submitted to the Mathematical Sciences Program Review Chair for final approval.

Here are some examples of 5/3 units of coursework for four thematically-related minors. Other options are available.

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For more information about the Mathematics minor, see Professor Farr, who is the coordinator for Mathematics minors.
MECHANICAL ENGINEERING

G. TRYGGVASON, HEAD

ASSISTANT PROFESSORS: C. Furlong, I. Hussen, D. Lados, J. Liang, J. Van de Ven
VISITING ASSISTANT PROFESSOR: E. C. Cobb

MISSION STATEMENT
The Mechanical Engineering program at WPI aims to graduate students who have the broad expertise required to confront real world technological issues that arise in our society. Students in the program are educated to apply scientific principles and engineering methods to analyze and design systems, processes, and products that, when engineered properly, improve the quality of our lives. The Mechanical Engineering program is consistent with the WPI philosophy of education, in which each student develops the tools required for self-learning, and the sensibility to consider the impact of technology on society in the decisions they will make as engineering professionals.

PROGRAM EDUCATIONAL OBJECTIVES
The Mechanical Engineering Program seeks to have alumni who:
- are successful professionals because of their mastery of the fundamental engineering sciences, and mechanical engineering and their understanding of the design process.
- are leaders in business and society due to a broad preparation in technology, communication, teamwork, globalization, ethics, business acumen and entrepreneurship.
- will use their understanding of the impact of technology on society for the betterment of humankind.

PROGRAM OUTCOMES
Graduating students should demonstrate that they attain the following:
- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to function on multi-disciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in lifelong learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
- an ability to apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyze, design, and realize physical systems, components or processes
- an ability to work professionally in both thermal and mechanical systems areas

Program Distribution Requirements for the Mechanical Engineering Major
The normal period of residency at WPI is 16 terms. In addition to WPI requirements applicable to all students (see page 9), students wishing to receive the ABET-accredited degree designated “Mechanical Engineering” must satisfy certain additional distribution requirements. These requirements apply to 10 units of study in the areas of mathematics, basic science, and engineering science and design as follows:

REQUIREMENTS MINIMUM UNITS
1. Mathematics and Basic Science (Notes 1, 2, 3). 4
2. Engineering Science and Design (includes MQP) (Notes 3, 4, 5, 6, 7, 8, 9). 6

NOTES:
1. Must include a minimum of 5/3 units of mathematics, including differential and integral calculus and differential equations.
2. Must include a minimum of 1/3 unit in chemistry and 2/3 unit in physics, or 1/3 unit in physics and 2/3 unit in chemistry.
3. Must include an activity that involves basic matrix algebra and the solution of systems of linear equations, and an activity that involves data analysis and applied statistical methods.
4. Must include 1/3 unit in each of the following: electrical engineering, materials science, and mechanical engineering experimentation.
5. Must include at least one unit of ME courses at the 4000-level.
6. Must include 1/3 unit in each of the following: electrical engineering, materials science, and mechanical engineering experimentation.
7. Must include two stems of coherent course and/or project offerings as noted below in a and b.
   a. A minimum of one unit of work in thermofluid systems that includes the topics of thermodynamics, fluid mechanics and heat transfer, plus an activity that integrates thermofluid design.
   b. A minimum of one unit of work in mechanical systems that includes the topics of statics, dynamics, and stress analysis, plus an activity that integrates mechanical design.
8. Must include an activity which realizes (constructs) a device or system.
9. Must include 1/3 unit of Capstone Design Experience.

Items 3, 5, 7a integration, 7b integration, 8, 9 may all be "multiple-counted."
STUDENTS EARNING A B.S. DEGREE IN MECHANICAL ENGINEERING MUST COMPLETE 15 UNITS OF STUDY, DISTRIBUTED AS FOLL
OWS:

<table>
<thead>
<tr>
<th>4 UNITS OF NON-TECHNICAL ACTIVITIES</th>
<th>2 UNITS H&amp;A SUFFICIENCY</th>
<th>See WPI Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 UNIT INTERACTIVE QUALIFYING (IQP) PROJECT</td>
<td>See WPI Requirements</td>
</tr>
<tr>
<td></td>
<td>2/3 UNIT SOCIAL SCIENCE</td>
<td>See WPI Requirements</td>
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<tr>
<td></td>
<td>1/3 UNIT PHYSICAL EDUCATION</td>
<td>See WPI Requirements</td>
</tr>
</tbody>
</table>

| 1 UNIT FREE ELECTIVE | 1 UNIT FREE ELECTIVE | See Catalog |

<table>
<thead>
<tr>
<th>4 UNITS OF MATHEMATICS AND BASIC SCIENCE</th>
<th>5/3 Units Differential &amp; Integral Calculus and Ordinary Differential Equations</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>3/3 Units One Chemistry and Two Physics, OR One Physics and Two Chemistry</td>
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<tr>
<td></td>
<td>4/3 Units Student Selected Courses from the General Category of Mathematics and/or Basic Science</td>
</tr>
</tbody>
</table>

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<tr>
<th>6 UNITS OF MECHANICAL ENGINEERING (Notes 1 &amp; 2)</th>
<th>1 unit required</th>
<th>1 unit required</th>
<th>1 unit required</th>
<th>1 unit required</th>
<th>2 units required</th>
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</thead>
<tbody>
<tr>
<td>MECHANICAL SYSTEMS</td>
<td>ME 2501</td>
<td>ES 2502</td>
<td>ES 2503</td>
<td>ES 2502</td>
<td>ES 2503</td>
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<tr>
<td>THERMOFLUID SYSTEMS</td>
<td>ES 3001</td>
<td>ES 3003</td>
<td>ES 3004</td>
<td>ES 3001</td>
<td>ES 3003</td>
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<tr>
<td>OTHER COURSES</td>
<td>ES 2001</td>
<td>ECE 3601</td>
<td>ME 3901</td>
<td>ES 2001</td>
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<tr>
<td>MAJOR QUALIFYING PROJECT (MQP)</td>
<td>ME 3310</td>
<td>ME 3311</td>
<td>ME 3320</td>
<td>ME 3320</td>
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<tr>
<td>ELECTIVES</td>
<td>ME 4320</td>
<td>ME 4430</td>
<td>ME 4770</td>
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<td>ME 3506</td>
<td>ME 4771</td>
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<td>ME 4429</td>
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<td>ME 3323</td>
<td>ME 1800</td>
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<td>ME 2300</td>
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<td>ME 4810</td>
<td>ME 4429</td>
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<tr>
<td></td>
<td>ME 4430</td>
<td>ME 4770</td>
<td>(depending on topic)</td>
<td>ME 4430</td>
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<td>ME 3506</td>
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<td>ME 3506</td>
<td>ME 4810</td>
<td>(depending on topic)</td>
<td>ME 3506</td>
<td>(depending on topic)</td>
</tr>
</tbody>
</table>

The courses listed above can be replaced by other equivalent courses, with approval by the ME Program Committee.

**Note 1:** A complete program must include an activity in each of the following six categories. Courses used to satisfy these activities can be multiple-counted. They can be used to simultaneously satisfy the mechanical engineering, mathematics and basic science, and free elective requirements.

**Note 2:** Elective courses from other engineering disciplines may also be selected at the 2000, 3000 or 4000 levels.
Each Mechanical Engineering student must complete a Capstone Design experience requirement. This capstone design experience is partially or fully accomplished by completing a Major Qualifying Project which integrates the past course work and involves significant engineering design. At the time of registration for the MQP, the project advisor will determine whether the MQP will meet the Capstone Design requirement or not. If not, the advisor will identify an additional 1/3 unit of course work in the area of design (ME 4320, ME 4429, ME 4430, ME 4770, or ME 4810) to be taken in order to meet the ABET Capstone Design requirement.

MECHANICAL ENGINEERING DEPARTMENT CONCENTRATIONS

AERONAUTICS (GATSONIS)
Students are provided with ample opportunity to develop technical competence in low- and high-speed aerodynamics, aircraft propulsion systems, structures, and aircraft design. Experimental and computational facilities are available for course and projects. Typical MQPs include: the design, construction, and testing of remotely piloted aircraft and micro aerial vehicles; experimental and computational aerodynamics; flow and structural control; parachute aerodynamics.

Aerodynamics
2 Courses Required
- ME 3410 Compressible Fluid Dynamics
- ME 3711 Aerodynamics

4 Courses Selected
- ME 3712 Aerospace Structures
- ME 4710 Gas Turbines for Propulsion and Power Generation
- ME 4718 Materials with Aerospace Applications
- ME 4723 Aircraft Dynamics and Controls
- ME 4733 Guidance, Navigation and Communication
- ME 4770 Aircraft Design

*Plus Aeronautics related MQP

ASTRONAUTICS (GATSONIS)
Students are provided with ample opportunity to develop technical competence in spacecraft dynamics, rocket propulsion, guidance and controls, space structures, and space systems design. Experimental and computational facilities are available for course and projects. Typical MQPs include: design and testing of recoverable rockets; experiments in electric propulsion and micro-propulsion; experiments in formation flying and spacecraft control.

Astronautics
2 Courses Required
- ME 2713 Astronautics
- ME 4713 Spacecraft Dynamics and Controls

4 Courses Selected
- ME 3410 Compressible Fluid Dynamics
- ME 3712 Aerospace Structures
- ME 4718 Materials with Aerospace Applications
- ME 4719 Rocket Propulsion
- ME 4733 Guidance, Navigation and Communication
- ME 4771 Spacecraft and Mission Design

*Plus Astronautics related MQP

BIOMECHANICAL (HOFFMAN)
Students blend biology and biotechnology coursework with continuum mechanics, biomechanics, biofluids, and biomedical materials to support their individual interest. MQPs are usually developed jointly with off-campus medical facilities, including the University of Massachusetts Medical Center.

Typically MQP topics include: soft tissue mechanics, flow in constricted blood vessels, joint kinematics, prosthetic devices, sports biomechanics, biomaterials, tissue engineering and rehabilitation.

Biomechanical
Two (2) Biology and Biotechnology (BB) Courses
Select 4
- ME 3501 Elementary Continuum Mechanics
- ME 3506 Rehabilitation Engineering
- ME 4504 Biomechanics
- ME 4606 Biofluids
- ME 4814 Biomedical Materials

Any BME course at the 3000-level or higher

*Plus Biomechanical-related MQP

ENGINEERING MECHANICS (HOU)
Students select courses to develop the ability to construct models to analyze, predict, and test the performance of solid structures, fluids, and composite materials under various situations.

Typical MQP topics include: mechanical vibrations, stress and strain analysis, computer methods in engineering mechanics, finite element analysis, and vibration isolation. Departmental testing facilities and computer and software support are available.

Engineering Mechanics
Select 6
- ME 3501 Elementary Continuum Mechanics
- ME 3506 Rehabilitation Engineering
- ME 3602 Incompressible Fluid Dynamics
- ME/BME 4504 Biomechanics
- ME 4505 Advanced Dynamics
- ME 4506 Mechanical Vibrations
- ME 4512 Introduction to the Finite Element Method

*Plus Engineering Mechanics MQP

MANUFACTURING (RONG)
Courses are available to support student interest in manufacturing engineering, computer-aided design, computer-aided manufacturing, robotics, vision systems, and a variety of manufacturing processes. Typical MQPs include: robotics, composite materials, factory automation, materials processing, computercontrolled machining, surface metrology, fixtureing, machine dynamics, grinding, precision engineering, prototype manufacturing.

See also the Manufacturing Engineering degree program.

Manufacturing
Select 2
- ME 1800 Materials Selection and Manufacturing Processes
- ME 2820 Materials Processing
- ME 3023 Mechanical Behavior and Modeling Properties of Engineering Materials
- ME 4810 Automotive Materials and Process Design
- ME 4821 Plastics

Select 2
- ES 3011 Control Engineering I
- ME 3820 Computer-Aided Manufacturing
- ME/RBE 4815 Industrial Robotics

Select 2
- OIE 2850 Engineering Economics
- OIE 3400 Production System Design
- OIE 3401 Production Planning and Control

*Plus Manufacturing MQP
MATERIALS SCIENCE AND ENGINEERING (SISSON)
Students interested in a strong materials science and engineering component can elect course and project activities in metals, ceramics, polymers, and composite materials with laboratory and project experience using facilities in Stoddard Laboratories.

Typical MQP topics include: X-ray diffraction, electron microscopy, computer modeling, mechanical testing and deformation mapping, plastic deformation, ceramic processing, friction, wear, corrosion, and materials processing.

Another option in the materials program is a Minor in Materials, which is described under Materials Engineering in this catalog.

Materials Science and Engineering
Select 2
ME 2820 Materials Processing
ME 4810 Automotive Materials and Process Design
Select 2
ME 4813 Ceramics and Glasses for Engineering
ME 4814 Biomedical Materials
ME 4821 Plastics
ME 4832 Corrosion and Corrosion Control
ME 4875 Introduction to Nanomaterials and Nanotechnology
Select 2
ME 3801 Experimental Methods in Materials Science and Engineering
ME 4840 Physical Metallurgy
Any 500-level MTE course
* Plus Materials Science MQP

MECHANICAL DESIGN (NORTON)
Courses are available to support development of student interest in the design, analysis, and optimization of an assembly of components which produce a machine. Computer-based techniques are widely used in support of these activities.

Typical MQP topics are: optimum design of mechanical elements, stress analysis of machine components, evaluation and design of industrial machine components and systems, robotics, and computer-aided design and synthesis.

Mechanical Design
2 Required
ME 3310 Kinematics of Mechanisms
ME 3320 Design of Machine Elements
Select 4
ES 1310 Engineering Design Graphics
ES 3323 Introduction to CAD
ME 2300 Introduction to Engineering Design
ME 3311 Dynamics of Mechanisms and Machines
ME 3321 Dynamic Modeling
ME 3506 Rehabilitation Engineering
ME 4320 Advanced Engineering Design
ME/RBE 4322 Modeling and Analysis of Mechatronic Systems
ME 4810 Automotive Materials and Process Design
ME/RBE 4815 Industrial Robotics
* Plus Mechanical Design MQP

ROBOTICS (RONG)
Students select courses to give them a solid foundation in the various aspects of robotics, including kinematics and actuators, sensors, and control and computing. In addition to relevant mechanical engineering courses, students can select courses from electrical engineering and computer science.

Typical MQP topics include designing of robots and robotic components, including mobile ground robots, aerial robots and underwater robots, automatic assembly and industrial robotics applications, and development of software and control algorithms for individual robots and robotic swarms.

Robotics
3 Required
RBE 1001 Introduction to Robotics
ES 3011 Control Engineering I or ME 3310 Kinematics of Mechanisms
ME/RBE 4322 Modeling and Analysis of Mechatronic Systems or ME/RBE 4815 Industrial Robotics
Select 3
ES 3011 Control Engineering I (If not selected above)
ES 3323 Advanced Computer-aided Design
ME 3310 Kinematics of Mechanisms (If not selected above)
ME/RBE 4815 Industrial Robotics (If not selected above)
ECE 2311 Continuous-Time Signal and System Analysis
ECE 2312 Discrete-Time Signal and System Analysis
ECE 2801 Foundations of Embedded Computer Systems
ECE 4703 Real Time Digital Signal Processing
CS 2102 Object-Oriented Design Concepts
CS 2301 Systems Programming for Non-Majors or CS 2303 Systems Programming Concepts
CS 3733 Software Engineering or CS 3133 Foundations of Computer Science
CS 4341 Introduction to Artificial Intelligence
CS 4731 Computer Graphics or 4732 Computer Animation
CS 4120 Analysis of Algorithms
* Plus Robotics MQP

*Others courses with approval from the ME Undergraduate Committee.

THERMAL-FLUID ENGINEERING (OLINGER)
Students study the theoretical and empirical bases of thermodynamics, heat transfer, mass transfer, and fluid flow, as well as the application of these fundamental engineering sciences to energy conversion, environmental control, and vehicular systems.

Typical MQPs include: biological fluid mechanics, laminar/turbulent separation, lifting bodies, heat pipes, electronic component cooling, power cycles, fluid component analysis and design, and energy storage.

Thermal-Fluid Engineering
3 Required
ME 3602 Incompressible Fluid Dynamics
ME 3410 Compressible Fluid Dynamics
ME 4429 Thermodynamic Applications or ME 4710 Gas Turbines for Propulsion and Power Generation
Select 3
ES 3002 Mass Transfer
ME 3501 Continuum Mechanics
ME 3711 Aerodynamics
ME 4429 Thermodynamic Applications
ME 4606 Biofluids
ME 4710 Gas Turbines for Propulsion and Power Generation
ME 4719 Rocket Propulsion
* Plus Thermal-Fluids related MQP

NOTES:
1. A Concentration area requires a 1 unit of MQP in that area.
2. After consultation with their academic advisor, students may petition the M.E. Dept. Curriculum Committee for approval of a Concentration plan at any time, preferably prior to the middle of their Junior Year.
ENHANCED PROGRAMS

BACHELOR/MASTER’S PROGRAM IN MECHANICAL ENGINEERING
Outstanding students are encouraged to combine a master’s degree with their undergraduate WPI studies. Details are found in the WPI GRADUATE PROGRAM section of this catalog, and interested students should initiate discussions with their advisor early in their junior year.

COOPERATIVE EDUCATION PROGRAM
The WPI Cooperative Education Program provides an opportunity to integrate “real-world” experience into an educational program. Details are found in the COOPERATIVE EDUCATION PROGRAM section on page 185.

MECHANICAL ENGINEERING MINOR (FOR NON-MAJORS)
Non-ME majors interested in developing a ME minor in conjunction with their major should consult with the Department Head or the lead faculty member in the specific ME sub-area of interest to define a program leading to recognition of the minor. Each individual student minor must then be approved by the Committee on Academic Operations.

MILITARY SCIENCE

LTC N. A. GAUTHIER, HEAD
PROFESSOR: LTC N. A. Gauthier
ASSISTANT PROFESSORS: MAJ F. Pagaduan, CPT D. Hudson, CPT T. Painter, MSG S. Cascalheira, SFC P.B. Riddick

MISSION STATEMENT
The Military Science and Leadership Program (Army ROTC) is a premiere leadership and management program offered by WPI. Open to all students within the Worcester Consortium, the program is designed to teach valuable leadership skills and managerial traits that will prepare students for careers in the private and public sectors. Students partake in this hands-on experience that integrates traditional coursework with innovative challenging training. They develop strong decision-making

MILITARY SCIENCE COURSE FLOW CHART

(1) Required for 2 year ROTC program students.
(2) Additional requirements: Professional Military Education.
Five Undergraduate Courses.
Leadership Laboratories, weekly.
Physical Training, weekly.
Weekend Field Training Exercise (2 each year).
Social Events.
(3) Required attendance for all Juniors and Seniors.
and organizational management skills, team-building and interpersonal skills, as well as learn time and stress management techniques.

OBJECTIVES AND OUTCOMES
Students that participate in Army ROTC while pursuing their undergraduate and graduate studies are extremely marketable and highly sought after for their distinctive leadership capabilities. As technology transforms organizations, the desire for multi-faceted leaders has increased; the WPI Army ROTC prepares adaptable leaders for the future.

PROGRAM DESCRIPTION(S)
The Military Science and Leadership program is intended to be a four-year program that encourages personal growth and development.

BASIC COURSE
The first two years make up the Basic Course, which serves as the foundation to the program. During the Basic Course, the curriculum focuses on aspects of leadership, team-building, and communication skills. Students participate in adventure training, such as orienteering, rappelling, and paintball that puts their classroom learning to practice.

Students may participate in the first two years of the program commitment-free. Students awarded full-tuition scholarships or participate in the Advanced Course do incur a service obligation and may serve in the Army either full-time or part-time.

ADVANCED COURSE
The Advanced Course is a more intensive leadership program that is taken during the Junior and Senior years or during two years of graduate studies. The curriculum continues to concentrate on problem-solving and building teams, but also introduces military tactics and ethics.

Students interested in earning a commission as an Army Officer are required to enroll in the Advanced Course and attend the Leadership Development and Assessment Course (LDAC). LDAC is a five-week course that students are paid to attend during the summer and is the culmination of the training that the students receive while on campus. If students decide later in their academic career that they would like to pursue Army ROTC, there are alternate entry options to prepare them for the Advanced Course.

Students attending on Army ROTC Scholarships or that are enrolled in the Advanced Course receive a monthly stipend and $900 per year for books. Freshman receive $300 per month, Sophomores receive $350 per month, Juniors receive $450 per month, and Seniors receive $500 per month. Students interested in pursuing scholarships or enrolling in the Advanced course are required to meet eligibility requirements.

PHYSICAL EDUCATION, RECREATION, AND ATHLETICS

D. L. HARMON, HEAD
ASSOCIATE PROFESSOR: P. J. Grebinar

REQUIREMENTS
Qualification in physical education shall be established by completing 1/3 unit of course work. Students are urged to complete this requirement in their first two years of residency at WPI. In addition to general PE course offerings, students may satisfy their PE requirement in the PE 1100-series courses noted below:

1. WPI approved varsity athletic team participation. Student must be registered in advance of participation.
2. Club Sports. Students must be members of a PE approved club prior to becoming eligible for physical education credit. Students must be registered in advance of participation.
3. Approved courses not offered at WPI; advance approval by the Physical Education Department is necessary.
4. Individualized program at WPI; advance approval by the Physical Education Department is necessary.

Students who wish to obtain PE credit by the above means must be enrolled in a course in the PE 1100 series.

Participation in certain ROTC programs may entitle students to a receive PE credit.

ATHLETIC PROGRAMS

THE INTERCOLLEGIATE PROGRAM
The intercollegiate athletics program offers competition in 20 varsity sports.

All full-time members of the physical education faculty and staff are involved in coaching, with assistance from other faculty members and part-time coaches from the community who have special skills in athletics.

WPI has excellent facilities and provides the best in protective equipment but, if an injury should occur, a team physician and full-time trainers are available, offering the latest treatment methods and facilities.

Practices are normally held daily, after 4 pm. Midweek contests involving travel are held to a minimum to avoid missing classes. Every effort is made to avoid conflicts with academic activities, and competitions are generally scheduled with schools with similar standards and objectives.

In recent years, teams and individuals have been sent to regional and national tournaments to allow them to compete at the highest possible level. All-America recognition has been attained recently in football, men’s soccer, track and field, and wrestling.

The athletic program forms an important point of contact with other universities and colleges in the East and is an opportunity for our students to compete against conference and independent institutions.
THE CLUB SPORTS PROGRAM
The Club Sports Program offers a variety of competitive activities for student participation. Some of the current Club Sports include:

- **Club Sports**
  - Alpine Skiing
  - Cheerleaders
  - Soccer
  - Fencing
  - Free Style Wrestling
  - Golf
  - Ice Hockey
  - Lacrosse
  - Martial Arts (SOMA)
  - Rugby
  - Sailing
  - Scuba
  - Tennis
  - Ultimate Frisbee
  - Volleyball (men)
  - Water Polo
  - Cheerleaders
  - Rugby
  - Sailing
  - Scuba
  - Tennis
  - Ultimate Frisbee
  - Volleyball (men)
  - Water Polo

Club Sports, Class II, are administered through the Department of Physical Education, Recreation, and Athletics and details regarding the activities listed above are available through the Coordinator of Club Sports in Alumni Gymnasium.

THE INTRAMURAL PROGRAM
The Intramural Program is designed as an opportunity for students to enjoy the benefits of recreation and athletic competition even though they may not have the time, talent or desire to compete on the higher intercollegiate level.

Entries are welcome not only from fraternities, sororities and other residential units but also from a variety of independent student groups and individuals, including faculty and staff. Approximately 50% of the student body participate in intramurals.

The program includes flag football, floor hockey, racquetball, volleyball, basketball, soccer, softball, and bowling. The program is ever-expanding, and activities are added as needs arise and time and facilities permit.

The program is administered by the Department of Physical Education and Athletics, and all details regarding scheduling and eligibility are available on the department website.

PROGRAM EDUCATIONAL OBJECTIVES
The physics department educates students with a program characterized by curricular flexibility, student project work, and active involvement of students in their learning. Through a balanced, integrated curriculum stressing the widely applicable skills and knowledge of physics, we provide an education that is strong both in fundamentals and in applied knowledge, appropriate for immediate use in a variety of fields as well as graduate study and lifelong learning.

PROGRAM OUTCOMES
We expect that physics graduates:

1. Know, understand, and use a broad range of basic physical principles.
2. Have an understanding of appropriate mathematical methods, and an ability to apply them to physics.
3. Have demonstrated oral and written communications skills.
4. Understand options for careers and further education, and have the necessary educational preparation to pursue those options.
5. Have an ability to learn independently.
6. Have acquired the broad education envisioned by the WPI Plan.
7. Are prepared for entry level careers in a variety of fields, and are aware of the technical, professional, and ethical components.
8. Are prepared for graduate study in physics and/or other fields.
9. Can find, read, and critically evaluate selected original scientific literature.

Program Distribution Requirements for the Physics and Engineering Physics Majors
The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 9), completion of a minimum of 10 units of study is required in the areas of mathematics, physics, and related fields as follows:

**PHYSICS**

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
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<tbody>
<tr>
<td>1. Mathematics (Note 1)</td>
<td>3</td>
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<tr>
<td>2. Physics (including the MQP) (Notes 2, 3)</td>
<td>5</td>
</tr>
<tr>
<td>3. Other subjects to be selected from mathematics, science, engineering, computer science, and management (Note 3)</td>
<td>2</td>
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</tbody>
</table>

**NOTES:**

1. Mathematics must include at least 2/3 unit of mathematics at the level of MA 3000 or higher.
2. ES 3001 and CH 3510 count as physics courses.
3. Either item 2 or 3 must include at least 1/3 unit from each of the five principal areas of physics: mechanics, experimental physics, electromagnetism, quantum mechanics, and thermal and statistical physics. This core distribution requirement is satisfied by successfully completing at least one course from each of the following five sets of courses: PH 2201 or 2202 (mechanics); PH 2651 or 2601 (mechanics); ES 3001, CH 3510 or PH 4206 (thermo and statistical physics); or other courses approved by the department Program Review Committee following petition by the student.
PhysicS and engineerIng-physicS proGrarms

For a student entering the study of physics, there is a natural progression of subjects which provide a foundation for advanced work within physics and engineering-physics programs. This constitutes a core sequence which embodies the following indispensable basic areas of study: classical mechanics, electromagnetism, a survey of modern physics, statistical and quantum physics, and laboratory experimental methods. Because the language of the exact sciences is mathematics, there is a parallel core sequence of mathematics courses normally taken either as preparation for or concurrently with the physics courses with which they are paired in the list presented below. In the following table indicates that the mathematics course is strongly recommended; indicates that concurrent study is acceptable.

MA 1021 Calculus I → PH 1110 Mechanics
MA 1022 Calculus II → PH 1120 Electricity and Magnetism
MA 1023 Calculus III → PH 1111 Mechanics
MA 1024 Calculus IV → PH 1121 Electricity and Magnetism
MA 1023 Calculus III → PH 1130 Introduction to 20th Century Physics
MA 1024 Calculus IV → PH 1140 Oscillations and Waves
MA 2051 Differential Equations → PH 2202 Intermediate Mechanics II
MA 2071 Linear Algebra → PH 2651 Physics Laboratory
MA 2251 Vector/ Tensor Calculus → PH 2301 Electromagnetic Fields I
MA 4451 Boundary Value Problems → PH 3301 Electromagnetic Theory
PH 3401 Quantum Mechanics I → PH 4206 Statistical Physics

Students needing a somewhat more gradual introduction and an opportunity to gain mathematical skills concurrently are advised to substitute these courses for PH 1111 and PH 1121.

Physics and engineering-physics students should also reserve part of their undergraduate experience for developing perspective in a range of other science and engineering disciplines. A few of the many possibilities are illustrated by the following examples.

- Chemistry (CH 1010, 1030); Material Science (ES 2001). Choosing appropriate materials is often crucial in the development of new experimental techniques that can further our knowledge of physical phenomena. Conversely, the studies of physicists have had profound effects on the development of new materials.

- Electronics, both analog (ECE 2201 and 3204, and digital (ECE 2302). Electronics pervades the modern laboratory. It is valuable to learn electronic principles and designs as they are applied in modern "on-line" experimental data collection and data reduction systems.

- Computer science (CS 1101 or 1102 and CS 2301). Physics students will need to make skillful use of computers in present and future experimental data processing, theoretical analyses, and the storing, retrieving and displaying of scientific information.

- Engineering courses related to science. Some basic knowledge in areas such as heat transfer, control systems, fluid mechanics, stress analysis and similar topics will prove to be of great benefit to the physicist called upon to apply professional knowledge to practical engineering problems.

Building on this core and topical subject coverage, physics students are in a position to turn in any number of directions within the range of physics studies, depending on individual interests and career objectives. Six illustrative examples are outlined below. In each case the outline includes a list of recommended and related courses followed by a sampling of project opportunities in the respective areas. Selection of specific courses and projects should be determined by students' interests and the guidance of their academic advisors and the engineering-physics coordinator. For courses outside of the physics department, students are advised to discuss the prerequisites with the instructor.

1. Physics

Recommended Courses

PH 3402 Quantum Mechanics II
PH 4201 Advanced Classical Mechanics
PH (IS/P) Selected Readings in Physics

Related Courses

ECE 2311 Continuous-Time Signal and System Analysis
ECE 2312 Discrete-Time Signal and System Analysis
ECE 3801 Advanced Logic Design
ECE 3901 Semiconductor Devices
ES 3011 Control Engineering I
PH 2510 Atomic Force Microscopy
PH 3501 Relativity
PH 3502 Solid State Physics
PH 3503 Nuclear Physics
PH 3504 Optics
PH (IS/P) Modern Optics
PH 501 (Graduate) Mathematical Methods of Physics I
PH 511 (Graduate) Classical Mechanics
MA 4291 Applicable Complex Variables

2. Computational Physics.

Recommended Courses

MA 3257 Numerical Methods for Linear and Non-Linear Systems
MA 4411 Numerical Solutions of Differential Equations
PH (IS/P) Numerical Techniques in Physics

Related Courses

PH 3402 Quantum Mechanics II
PH 3502 Solid State Physics
PH 501/2 (Graduate) Mathematical Physics
MA 3457/8 Numerical Methods for Calculus and
CS 4033 Differential Equations
MA 4291 Applicable Complex Variables
CS 1101 Introduction to Program Design
CS 2011 Introduction to Computer Organization and Assembly Language
CS 2301 Systems Programming for Non-Majors
CS 4731 Computer Graphics
ECE 2311 Continuous-Time Signal and System Analysis
ECE 2312 Discrete-Time Signal and System Analysis
ECE 3801 Advanced Logic Design
ES 3011 Control Engineering I
3. Optics

Recommended Courses
- PH 3504 Optics
- PH 2501 Photonics
- PH 2502 Lasers

Related Courses
- PH 3402 Quantum Mechanics II
- PH 3502 Solid State Physics
- PH 542/3 (Graduate) Modern Optics I and II
- MA 4291 Applicable Complex Variables
- AR/ID 3150 Light, Vision, and Understanding
- ECE 2311 Continuous-Time Signal and System Analysis
- ECE 2312 Discrete-Time Signal and System Analysis
- ES 3011 Control Engineering I

4. Electromagnetism

Recommended Courses
- PH (IS/P) Modern Optics
- PH (IS/P) Selected Readings in Electromagnetism

Related Courses
- PH 3402 Quantum Mechanics II
- PH 3502 Solid State Physics
- PH 3503 Nuclear Physics
- PH 3504 Optics
- PH 533 (Graduate) Electromagnetic Theory
- PH 514/5 (Graduate) Quantum Mechanics
- MA 4291 Applicable Complex Variables
- ECE 2311 Continuous-Time Signal and System Analysis
- ECE 2312 Discrete-Time Signal and System Analysis
- ES 3011 Control Engineering I

5. Nuclear Science And Engineering

Recommended Courses
- ES 2011 Introduction to Nuclear Technology
- PH 3503 Nuclear Physics

Related Courses
- PH 3402 Quantum Mechanics II
- PH 3501 Relativity
- PH 553 (Graduate) Nuclear Physics
- ME 4832 Corrosion and Corrosion Control
- ECE 3801 Advanced Logic Design
- ES 3011 Control Engineering I

6. Thermal Physics

Recommended Courses
- ES 3001 The Statistical Development of Classical Thermodynamics
- ES 3004 Fluid Mechanics
- PH (IS/P) Selected Readings in Thermal Physics

Related Courses
- ES 3003 Heat Transfer
- ES 3011 Control Engineering I
- ME 3410 Compressible Flow
- PH 3502 Solid State Physics
- PH 3504 Optics
- ME 4429 Thermodynamic Applications and Design
- ME 4602 Intermediate Fluid Dynamics
- PH 501/2 (Graduate) Mathematical Physics

PHYSICS MINOR

The Physics Minor offers non-Physics majors the opportunity to broaden their understanding of both the principles of physics and the application of those principles to modern day engineering problems. In these times of rapid technological change, knowledge of fundamental principles is a key to adaptability in a changing workforce.

Two units of coordinated physics activity are required for the Physics Minor, as follows (note that, in accordance with Institute policy, no more than 3/3 of these units may be double-counted toward other degree requirements):

1. Any ar all of the following four introductory courses:
   - PH 1110 or PH 1111
   - PH 1120 or PH 1121
   - PH 1130
   - PH 1140

2. At least 2/3 unit of upper level physics courses (2000 level or higher), which may include IS/P courses or independent studies approved by the program review committee. Examples of courses of this type which might be selected are (but are not limited to):
   - PH 2201 Intermediate Mechanics I
   - PH 2301 Electromagnetic Fields
   - PH 2651 Physics Laboratory
   - PH 3401 Quantum Mechanics I
   - PH 3504 Optics
   - PH 2501 Photonics
   - IS/P Quantum Engineering

Students who have taken the four course introductory sequence should have an adequate physics background for these courses; see, however, the individual course descriptions for the expected mathematical background. Other physics courses may be selected for the physics minor, but the recommended background for such courses often includes one or more of the courses listed above.

3. Capstone Experience

The capstone experience for the physics minor can be satisfied either by an independent study arranged for this purpose, or by one of the upper level courses. If the second option is chosen, the student must discuss this with the instructor prior to the start of the course. In either case, documentation of the capstone experience will consist of a paper, prepared in consultation with the instructor or independent study advisor, which incorporates and ties together concepts learned in the physics courses selected.

For more information, or assistance in selecting a minor advisor or an independent study advisor, see the Head of the Physics Department in Olin Hall 119.

Majors in Physics or Engineering Physics do not qualify for a Minor in Physics.
PRE-LAW PROGRAMS

ADVISORS: G. HEATON, K. RISSMILLER

Law schools do not require that undergraduates complete any particular course of study. Thus, students who complete degrees in engineering and science may wish to consider careers in law. Undergraduates interested in attending law school are encouraged to choose from among the many courses offered which explore legal topics. For those with greater interest, WPI offers a Minor in Law and Technology described on page 73. Courses with substantial legal content are listed among those courses fulfilling the requirements of the minor.

Enrolling in these courses will introduce students to the fundamentals of legal process and legal analysis. Students will study statutes, regulations and case law. These courses will, therefore, offer the student valuable exposure to the kind of material commonly studied in law schools and they may help demonstrate a student’s interest to law school admission committees. IQPs in Division 52, Law and Technology, or other projects that involve library research and extensive writing may also be helpful.

A pre-law advising program in the Social Science Department maintains information on careers in law, law schools, and the law school admission test (LSAT), which is universally required. Students may examine this material independently or make an appointment. Students with an interest in law are also encouraged to join the Pre-Law Society. To do so, contact Professor Rissmiller.

PRE-MBA PROGRAM (DUAL DEGREE)

ADVISOR: N. WILKINSON

FIVE-YEAR DUAL DEGREE BACHELOR/MBA PROGRAM

The combination of a technical undergraduate degree and a graduate degree in business has been cited by many experts as the ideal educational preparation for a career in private industry. For that reason, the Department of Management offers the opportunity for obtaining dual degrees (i.e., the Bachelor degree in engineering or science and the Master of Business Administration, MBA). The dual-degree program can be completed within five years, however, the program is demanding, and curriculum planning with the student’s advisor and the Department of Management should start by the beginning of the student’s third year at WPI at the very latest.

Only registered WPI undergraduates majoring in an engineering (excluding Management Engineering) or science area may enter the Dual-Degree Bachelor/MBA Program. A separate and complete application to the MBA program must be submitted. Admission to the Dual-Degree Bachelor/MBA Program is determined by the faculty of the Department of Management. The student should begin the curriculum planning process as early as possible in his/her undergraduate program, but no later than the beginning of the third year, to ensure that all of the required undergraduate courses are completed within the student’s four years of undergraduate study. It is recommended that the MBA application be submitted during the student’s Third Year of undergraduate study. A student in the Dual-Degree Bachelor/MBA Program continues to be registered as an undergraduate until the bachelor’s degree is awarded.

Students wishing to do a combined Bachelor/MBA must complete the following courses while an undergraduate:

- ACC 1100 Financial Accounting
- FIN 2200 Financial Management
- OBC 2300 Organizational Science
- MA 2611 Applied Statistics I
- MA 2612 Applied Statistics II
- OIE 3400 Production System Design
- MKT 3600 Marketing Management
- MIS 3700 Information Systems Management
- ECON 1110 Introductory Microeconomics
- ECON 1120 Introductory Macroeconomics
- BUS 515 Legal and Ethical Context of Technological Organizations

To obtain a bachelor’s degree via the Dual-Degree Bachelor/MBA Program, the student must satisfy all requirements for the bachelor’s degree, including distribution and project requirements.

To obtain an MBA via the Dual-Degree Bachelor/MBA Program, the student must satisfy all MBA degree requirements. In addition to the prerequisite undergraduate courses listed above, the student must complete the following graduate courses:

- OBC 511 Interpersonal and Leadership Skills for Technological Managers
- MKT 512 Creating and Implementing Strategy for Technological Organizations
- OIE 513 Creating Processes in Technological Organizations
- ACC 514 Business Analysis for Technological Managers
- BUS 515 Legal and Ethical Context of Technological Organizations
- BUS 516 Graduate Qualifying Project (GQP)
- 12 Elective Credits

A student in the Dual-Degree Bachelor/MBA Program may, with prior approval, apply the equivalent of a maximum of 12 graduate credits from the same courses toward both the bachelor’s and MBA degrees. Students in the Dual-Degree Bachelor/MBA Program may not take graduate-level management courses prior to their Fourth Year of undergraduate study, and then only provided the corresponding prerequisites have been satisfied.

The Department of Management may make other requirements as it deems appropriate in any individual case. These requirements take the form of a written agreement between the student and the Department of Management, and must be filed with the registrar before the student may be matriculated in the Dual-Degree Bachelor/MBA Program.

The Dual-Degree Bachelor/MBA Program is a full-time program of study. Once admitted to the Dual-Degree Bachelor/MBA Program, a student must register every fall and spring semester until the MBA is completed. A student in the Dual-Degree Bachelor/MBA Program who has no registered activities during a given fall or spring semester is automatically terminated from the Dual-Degree Bachelor/MBA Program, and may only be readmitted to the Dual-Degree Bachelor/MBA Program by the Department of Management’s Graduate Policy and Curriculum Committee and the Committee for Graduate Studies and Research via petition showing extenuating circumstances. Termination from the Dual-Degree Bachelor/MBA Program does not affect a student’s ability to continue toward the bachelor’s degree.
**PRE-MEDICAL, PRE-DENTAL AND PRE-VETERINARY PROGRAMS**

**ADVISOR: J. RULFS**

Students at WPI who wish to pursue careers in the medical professions should, in consultation with their academic advisors, plan their academic programs to include courses in biology, general and organic chemistry, and physics including laboratory experiences. Entry into medical or other health professions schools may be accomplished through any major program of study offered at WPI, although students majoring in some programs may have to use all of their electives to fulfill the required courses for medical school admission or may have to take some courses during summer sessions. It is important for students to work closely with their academic advisors as well as the pre-health advisor at WPI, to formulate an academic plan of study that will include the courses required for health professions schools. While each school may have specific and individual admissions requirements, typically these will include:

- **General chemistry** 3 courses
- **Organic chemistry** 3 courses
- **Biology** 3 courses
- **Physics** 3 courses
- **Calculus** 3 courses
- **English composition** 2 courses

* These courses must include laboratory components.
** Check with the pre-health advisor for the use of course and project work to fulfill this requirement.

Students should consult catalogs of the individual health professions schools for specific requirements.

The WPI projects system offers a tremendous advantage to pre-health professions students. Medical, dental and veterinary schools value teamwork, as well as cross cultural, research, and medically related experience, all of which can be demonstrated through project work. Opportunities for such projects can be found on campus or at one of the project center sites at the University of Massachusetts Medical Center or Tufts University School of Veterinary Medicine or through WPI’s global projects program. These projects provide students with valuable and unique experiences that can strengthen their commitment to a health profession and their application for admission to health professions schools.

Because students will leave WPI with a degree in an academic discipline, they will have other career opportunities should they decide not to pursue a career in a health profession or should they choose to work for some time after graduation before continuing on to a health professions school. Students or alumni applying to health professions school should plan to meet with the pre-health advisor to discuss the application process as well as to plan for a letter of recommendation from the pre-health office to support their application. These meetings should happen no later than the spring of the junior year or as soon as the decision is made to pursue admission to a health profession school.

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**PROJECT-BASED LEARNING COMMUNITY OPTION (PLC)**

See page 178 for detailed description.

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**ROBOTICS ENGINEERING**

**DIRECTOR: M. A. GENNERT**

**ASSOCIATED FACULTY:** H. K. Ault (ME), D. C. Brown (CS), M. J. Ciaraldi (CS), D. Cyganski (ECE), M. A. Demetriou (ME), R. J. Duckworth (ECE), A. E. Emanuel (ECE), M. S. Fofana (ME), C. Furlong-Vazquez (ME), M. A. Gennert (CS), A. H. Hoffman (ME), X. Huang (ECE), I. Hussein (ME), S. Jarvis (ECE), R. W. Lindeman (CS), F. J. Lofot (ECE), W. R. Michelson (ECE), R. L. Norton (ME), G. F. Pollice (CS), C. Rich (CS), Y. Rong (ME), L. E. Schachterle (Provost’s Office), K. A. Stafford (ME), G. Tryggvason (ME), J. Van de Ven (ME)

**MISSION STATEMENT**

Robotics—the combination of sensing, computation and actuation in the real world—is on the verge of rapid growth, driven by both supply and demand. The supply side is driven by decreasing cost and increasing availability of sensors, computing devices, and actuators. The demand side is driven by national needs for defense and security, elder care, automation of household tasks, customized manufacturing, and interactive entertainment. Engineers working in the robotics industry are mostly trained in one of Computer Engineering, Computer Science, Electrical Engineering, Mechanical Engineering, and Software Engineering. No single discipline provides the breadth demanded by robotics in the future.

**PROGRAM EDUCATIONAL OBJECTIVES**

The Robotics Engineering Program strives to educate men and women to

- Have a basic understanding of the fundamentals of Computer Science, Electrical and Computer Engineering, Mechanical Engineering, and Systems Engineering.
- Apply these abstract concepts and practical skills to design and construct robots and robotic systems for diverse applications.
- Have the imagination to see how robotics can be used to improve society and the entrepreneurial background and spirit to make their ideas become reality.
- Demonstrate the ethical behavior and standards expected of responsible professionals functioning in a diverse society.

**PROGRAM OUTCOMES**

Graduating students will have

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

### Program Distribution Requirements for the Robotics Engineering Major

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics (Note 1)</td>
<td>7/3</td>
</tr>
<tr>
<td>2. Basic Science (Note 2)</td>
<td>4/3</td>
</tr>
<tr>
<td>3. Entrepreneurship</td>
<td>1/3</td>
</tr>
<tr>
<td>4. Engineering Science and Design, including the MQP (Notes 3, 4, 5, 6, 7, 8, 9)</td>
<td>6 *</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Must include Differential and Integral Calculus, Differential Equations, Discrete Mathematics, and Probability or Statistics.
2. Must include at least 2/3 units in Physics.
3. Must include at least 5/3 units in Robotics Engineering.
4. Must include at least 1 unit in Computer Science, including Algorithms and Software Engineering.
5. Must include at least 2/3 units in Electrical and Computer Engineering, including Embedded Systems.
6. Must include at least 1/3 unit in Statics and 1/3 unit in Controls.
7. Must include at least 1/3 unit of Social Implications of Technology (CS 3043, GOV 2302, GOV/ID 2314, IMGD 2000, STS 2208).
8. Must include at least 1 unit from a list of Robotics Electives, of which at least 1/3 unit must be in Advanced Systems (CS 4341, ECE 3308, ME 3310).
9. The MQP must be a Capstone Design Experience in Robotics Engineering.
   * 6 units if GOV 2302, GOV/ID 2314, or STS 2208 are double-counted as meeting the Social Science Requirement and Engineering Science and Design Requirement.

**OTHER ROBOTICS PROGRAMS**

WPI students can also pursue specializations involving Robotics in several departments and programs. The department of Electrical and Computer Engineering and the department of Computer Science both encourage a focus on robotics, as detailed in their departmental descriptions. The department of Mechanical Engineering is developing a similar focus. All three of these departments have sponsored final capstone design projects involving the application of their disciplines to robotics.

Robotics activities are coordinated by Ken Stafford, Manager of Academic Initiatives and head of the WPI FIRST competitive program. He oversees an active lab where students design various robotics devices in the lower level of Higgins Laboratories. You may contact him for information at (508) 831-6122 or stafford@wpi.edu.

### SOCIAL SCIENCE AND POLICY STUDIES

**J. K. DOYLE, HEAD**

**PROFESSORS:** J. T. O’Connor, K. Saeed

**ASSOCIATE PROFESSORS:** J. K. Doyle, M. J. Radzicki, K. J. Rissmiller, J. M. Wilkes

**ASSISTANT PROFESSORS:** O. Pavlov, J. Skornko

**PROFESSOR OF PRACTICE:** J. Lynes

**ADJUNCT FACULTY:** W. Baller, R. Eberlen, A. Ford, J. Gobert, G. Heaton, J. Hines, B. Karanian, M. Miller, K. Warren

**RESEARCH ASSOCIATE PROFESSOR:** J. Gobert

### MISSION STATEMENT

SSPS programs are concerned with the substance and the process of social and economic problem solving especially as related to technological development, the environment, and public policy. Most social and economic problems go beyond the boundaries of the traditional social science disciplines. Hence, the courses offered by the Department of Social Science and Policy Studies attempt to integrate knowledge and research techniques from multiple disciplines. Our curriculum covers economics, sociology, psychology, system dynamics, law and political science. The department encourages students to view social and economic problems, and the relationship of technology to society, from a variety of perspectives and to become acquainted with different methods of gathering and analyzing social data.

The SSPS department offers undergraduate majors in several policy-related disciplines. In addition, the department administers WPI’s two-course requirement in the Social Sciences.

Complete descriptions of the department’s major and minor requirements, and recommendations for completing the social science requirement are available on the SSPS Department web site at www.wpi.edu/Academics/Depts/SSPS.

### PROGRAM OUTCOMES

Graduates of a social science major must have demonstrated through coursework and projects:

1. An ability to recognize patterns in real-world data, qualitative and quantitative, in order to be able to define problems.
2. An ability to formulate hypotheses and models representing problems and understand their logic.
3. An ability to experiment with hypotheses to establish their validity.
4. An ability to carry out appropriate analyses to arrive at effective solutions to addressing the defined problems.
5. Literacy in the technical aspects of a problem in the student’s area of concentration.
6. An ability to effectively communicate the results of an analysis.
7. An ability to work in groups.
Program Distribution Requirements for the Economic Science, Environmental Policy and Development, Psychological Science, Society, Technology and Policy, and System Dynamics Majors

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students, completion of a minimum of 10 units of study is required in social science, basic science, and mathematics as follows:

### ECONOMIC SCIENCE

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Economics (Note 1)</td>
<td>3</td>
</tr>
<tr>
<td>2. Economics and/or Management (Note 2)</td>
<td>2/3</td>
</tr>
<tr>
<td>3. Other Social Science</td>
<td>1</td>
</tr>
<tr>
<td>4. Modeling Techniques</td>
<td>2/3</td>
</tr>
<tr>
<td>5. Mathematics (Note 3)</td>
<td>2</td>
</tr>
<tr>
<td>6. Basic Science</td>
<td>1</td>
</tr>
<tr>
<td>7. Electives</td>
<td>2/3</td>
</tr>
<tr>
<td>8. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Must include courses in both micro and macro economic theory at the intermediate level and in econometrics and international trade (available through the Consortium or independent study).
2. Must include financial accounting, ACC1100. May include other relevant management courses as approved by the Departmental Program Review Committee.
3. Must include differential equations, integral calculus, and statistics.

### ENVIRONMENTAL POLICY AND DEVELOPMENT

<table>
<thead>
<tr>
<th>REQUIREMENTS (NOTE 1)</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Social Science and Policy Studies (Note 2)</td>
<td>4</td>
</tr>
<tr>
<td>2. Mathematics (Note 3)</td>
<td>5/3</td>
</tr>
<tr>
<td>3. Basic Science (Note 4)</td>
<td>2/3</td>
</tr>
<tr>
<td>4. Technical Concentration (Note 5)</td>
<td>2</td>
</tr>
<tr>
<td>5. Department Electives (Note 6)</td>
<td>2/3</td>
</tr>
<tr>
<td>6. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTES:**
1. 1/3 unit = 1 course. 15 units are required for graduation.
2. Students must complete 5/3 units (5 courses) in one of three social science areas: (a) economics, (b) psychology/sociology, (c) political science (includes SS & PS courses in law and policy analysis) and 2/3 unit (2 courses) in each of the other two social science areas. The particular courses chosen must include six out of the following nine courses: Environmental Problems and Human Cognition, American Public Policy, Development Economics, Environmental Economics, International Environmental Policy, Introduction to System Dynamics Modeling, Environmental Policy and Law, Governmental Decision Making and Administrative Law, and the Society-Technology Debate. Students must also complete three other social science courses (1 unit) of their choosing.
3. Must include both calculus and statistics.
4. Basic science courses must be selected from the disciplines of Physics, Chemistry, or Biology.
5. The technical concentration must include at least six thematically related courses in science, engineering or management that have been approved by the Department's Program Review Committee.
6. Departmental electives must be selected from the areas of mathematics, basic science, social science, or the technical concentration.

### PSYCHOLOGICAL SCIENCE

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Psychological Science (Note 1)</td>
<td>3</td>
</tr>
<tr>
<td>2. Psychological Science and/or Related Courses (Note 2)</td>
<td>1</td>
</tr>
<tr>
<td>3. Other Social Science (Note 3)</td>
<td>1</td>
</tr>
<tr>
<td>4. Basic Science, Computer Science, and/or Engineering (Note 4)</td>
<td>5/3</td>
</tr>
<tr>
<td>5. Mathematics (Note 5)</td>
<td>4/3</td>
</tr>
<tr>
<td>6. Electives (Note 6)</td>
<td>1</td>
</tr>
<tr>
<td>7. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Must include introductory psychology, social psychology, cognitive psychology, and research methods.
2. Related courses must be chosen from a list of psychology-related courses from other departments maintained by the Psychology Program Review Committee.
3. May include no more than two courses at the 1000-level.
4. Must include 1/3 unit of biology. Must include 1/3 unit of computer science (except CS 2022 and CS 3043).
5. Must include 2/3 units of calculus and 2/3 unit of statistics.
6. The 1 unit of electives must be coherently defined and approved by the Psychology Program Review Committee.

### SOCIETY, TECHNOLOGY AND POLICY

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Social Science (Notes 1, 2)</td>
<td>4</td>
</tr>
<tr>
<td>2. Minimum Basic Science background.</td>
<td>2/3</td>
</tr>
<tr>
<td>3. Minimum Mathematics background (Note 3)</td>
<td>1</td>
</tr>
<tr>
<td>4. Technical concentration (Note 4).</td>
<td>5/3</td>
</tr>
<tr>
<td>5. Electives (Note 5).</td>
<td>5/3</td>
</tr>
<tr>
<td>6. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Students must obtain approval of their proposed program from the Departmental Program Review Committee. Course distribution will focus on a disciplinary specialty and either policy analysis or a society-technology specialization such as Social Impact Analysis or Technology Assessment.
2. Relevant Humanities or Management courses approved by the Departmental Review Committee may be counted for a maximum of 2/3 of a unit in fulfilling the 4-unit requirement.
3. One course in calculus-based statistics is required.
4. A series of courses in one field of science, engineering, or management or a combination of courses approved by the departmental review committee which focus on issues to be developed in the MQP.
5. These courses are to be approved by the Departmental Review Committee and are meant to broaden the technical concentration and tie it to social concerns.

### SYSTEM DYNAMICS

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>MINIMUM UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. System Dynamics (Note 1)</td>
<td>5/3</td>
</tr>
<tr>
<td>2. Other Social Science (Note 2)</td>
<td>5/3</td>
</tr>
<tr>
<td>3. Management (Note 3)</td>
<td>2/3</td>
</tr>
<tr>
<td>4. Mathematics/basic sciences/engineering (Note 4)</td>
<td>8/3</td>
</tr>
<tr>
<td>5. Computer Science (Note 5)</td>
<td>2/3</td>
</tr>
<tr>
<td>6. Application Area (Note 6)</td>
<td>5/3</td>
</tr>
<tr>
<td>7. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>
NOTES:
1. Only social science courses with a “5” in the second digit of the course number count toward the system dynamics requirement.
2. Must include microeconomics or macroeconomics, cognitive or social psychology, and public policy.
3. Must include organizational science.
4. Must include differential and integral calculus, differential equations, and numerical or statistical analysis.
5. Courses on computer programming and programming languages are recommended.
6. This requirement is satisfied by a cohesive set of work from the fields of social science, management, science, mathematics, computer science, or engineering as specified in the curriculum the guidelines for system dynamics major.

DESCRIPTIONS OF CONCENTRATION AREAS AVAILABLE IN ECONOMIC SCIENCE
Economic Science majors may focus their studies by choosing a Concentration within one of the following two specific areas of Economics: Sustainable Economic Development and Computational Economics. These concentration areas reflect the growing importance of environmental issues and computational tools within the discipline of economics and are areas of strength in teaching and research in economic science at WPI. Concentrations within the Economics Science major comply with WPI’s requirements for concentrations. Students must complete an MQP and two units of integrated study in the area of their Concentration.

Sustainable Economic Development. The term sustainable economic development means choosing policies that balance environmental preservation and economic development so as to meet the needs of the present generation without seriously compromising the needs of future generations. The sustainable development concentration examines the economic, psychological, social, political, legal, and technical issues surrounding the creation of policies aimed at establishing sustainable economic systems at the local, national, and international levels.

1. 1 unit from the following list of courses in economic development:
   - ECON 2125 Development Economics
   - ECON 2117 Environmental Economics
   - CE 3070 Urban Environmental Planning
   - CE 3074 Environmental Analysis
   - HI 3333 Topics in American Technological Development

2. 1 unit from the following list of environmental courses in other social science disciplines, humanities, and biology, or additional courses from list 1:
   - BB 1002 Environmental Biology
   - BB 4140 Ecological Management
   - GOV 2311 Legal Regulation of the Environment
   - GOV 2312 International Environmental Policy
   - PSY 2405 Environmental Problems and Human Cognition
   - PY 2717 Philosophy and the Environment

Computational Economics. Students in the computational economics concentration supplement their knowledge of traditional tools of economic analysis by studying modern computational techniques. Student projects may address problems of complex macroeconomic modeling, chaos, computational finance, design of automated Internet markets, and many more. This concentration draws on the expertise and talent of the faculty in various departments throughout the university.

1. 1 unit from the following list of courses in system dynamics:
   - SD 1510 Introduction to System Dynamics Modeling
   - SD 1520 System Dynamics Modeling
   - SD 2530 Advanced Topics in System Dynamics Modeling
   - SD 3550 System Dynamics Seminar

2. 1 unit from the following list of courses offered in other departments:
   - BB 4250 Ecological Simulation Modeling
   - CS 2022/MA2201 Discrete Mathematics
   - CS 4032/MA3257 Numerical Methods for Linear and Nonlinear Systems
   - CS 4033/MA3457 Numerical Methods for Calculus and Differential Equations
   - CS 4341 Introduction to Artificial Intelligence
   - ES 3011 Control Engineering I
   - OIE 3460 Simulation Modeling and Analysis
   - OIE 3501 Management Science II: Risk Analysis
   - MA 2210 Mathematical Methods in Decision Making
   - MA 2431 Mathematical Modeling with Ordinary Differential Equations
   - MA 3471 Advanced Ordinary Differential Equations
   - MA 4235 Mathematical Optimization
   - MA 4411 Numerical Analysis of Differential Equations

DOUBLE MAJOR IN SOCIAL SCIENCE AND POLICY STUDIES
Any of the department majors programs outlined above may be taken as part of a double major in which the student majors in an area of science, engineering or management as well as social science. To obtain a double major, the student must satisfy all of the degree requirements of the technical discipline including an MQP and Distribution requirements. In addition, the double major in Social Science and Policy Studies requires four units of study in social science (inclusive of the normal two-course social science requirement) and the completion of a second qualifying project which combines the IQP and social science MQP into a single one-unit project. Unlike other double majors, the double major in Social Science and Policy Studies does not require three qualifying projects: two MQP’s and an IQP. However, the combined social science MQP and IQP must meet the goals of both. It must be interactive in nature involving an aspect of technology as well as in application of social science knowledge and analytical techniques. The decision to pursue the social science double major should be made fairly early in the student’s academic career, certainly early enough to ensure the selection of an appropriate IQP/MQP.
A Social Science Minor is available in any of the following disciplines:
- Economics
- Sociology
- Political Science and Law
- Psychology
- System Dynamics
- Social Science

A minor in the Social Sciences consists of 2 units of academic activity satisfying the following conditions:

1. Foundations
   Introductory level courses in any one or two social science disciplines taught at WPI: economics (ECON), sociology (SOC), political science (and law) (GOV), psychology (PSY), and system dynamics (SD). Introductory courses are identified by the first digit of the course number, which must be a 1. The second digit of the course number indicates the discipline (1—economics, 2—sociology, 3—political science and law, 4—psychology, and 5—system dynamics).

2. Applied Courses (At least 1 unit)
   Three or more higher level courses in the same social science discipline as the foundation courses, which involve applications or extensions of the material covered in the introductory courses and list the introductory courses as recommended background. High level courses have either a 2, 3, or 4 as the first digit of the course number. The capstone experience will consist of a paper in the last applied course taken. The paper must draw upon and integrate material covered in the previous courses. An IQP may provide the capstone experience and substitute for the last applied course provided that the IQP was advised or co-advised by a member of the Social Science & Policy Studies department, and contains appropriate social science analysis.

3. If five or more of the six 1/3 units required for the minor are in a single social science discipline, the title of the minor will be “Minor” in that discipline.* Otherwise the title of the minor will be “Minor in Social Science.” Examples of minor programs in economics, sociology, political science (and law), psychology, system dynamics and interdisciplinary social science are available at the SS & PS department office. The course selected for an interdisciplinary social science minor should follow an identifiable theme, such as the relationship between technology and society or social, political, economic or environmental policies.

Students taking minors in the social sciences are expected to designate a member of the SS & PS department as their SS minor advisor, who will assist them in preparing a program that meets the requirements of the minor. Students can obtain assistance at the SS & PS departmental office in designating an advisor.

Students completing any major in the Social Science and Policy Studies Department may not also complete a minor in social sciences.

* In designating sociology the minor, the course PSY 1402, Social Psychology, can be counted as one of the five courses required in Sociology. In designating the economics minor, at least 3 of the 5 required courses must be chosen from among the following four theory courses:
- ECON 1110 Introductory Microeconomics;
- ECON 1120 Introductory Macroeconomics;
- ECON 2210 Intermediate Microeconomics; and
- ECON 2120 Intermediate Macroeconomics.