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AIR FORCE AEROSPACE STUDIES

LTC SCOTT H. HILL, HEAD
PROFESSOR: Lt. Col. S. H. Hill
ASSISTANT PROFESSORS: Capt. D. C. Morrissette, Capt. A. M. Catino

INTRODUCTION
The Air Force Reserve Officer Training Corps (AFROTC) program offered at WPI is designed to provide a college student the opportunity to become an Air Force commissioned officer while completing requirements for an undergraduate or graduate degree. Enrollment is voluntary and open to young men and women who are U. S. citizens of good moral character and sound physical condition who seek the challenge of being an officer in the U. S. Air Force upon graduation from college. In addition to WPI students, students at any of the Worcester Consortium for Higher Education institutions are also eligible to apply for Air Force ROTC at WPI.

MISSION AND EDUCATIONAL OBJECTIVES
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 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.

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 for 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 one hour 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 $200 each month. POC who are not on scholarship are eligible to receive a POC tuition assistance incentive of $3000 a year.

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 five 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.

SCHOLARSHIP OPPORTUNITIES
By participating in Air Force ROTC, students may compete for Air Force scholarships ranging from two years to three years in duration. Full scholarships cover tuition, most fees, and a textbook allowance. Partial scholarships are also available which contribute up to 80% of fees and tuition, in addition to a textbook allowance. A tax-free subsistence allowance of $200 is paid to all scholarship students each academic month.

Entering freshmen may compete for an Air Force ROTC Four-Year Scholarship during their senior year in high school. Details of this program can be obtained by e-mailing afrotc@wpi.edu, by writing: Department of Aerospace Studies, WPI, 100 Institute Rd., Worcester MA 01609-2280, or through most high school counseling offices.

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 for GMC with one additional hour for POC.

This formal military training is largely planned and directed by the officer candidates. The freshmen and sophomores are involved in such initial leadership experiences as Air Force customs and courtesies; squadron and flight drill movements; Air Force educational benefits; Air Force career opportunities; and preparation for field training. The juniors and seniors are involved in more advanced leadership experiences as they become more responsible for the planning and organizing of wing activities, to include conducting the Leadership Laboratory itself.

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Field Training:
Field Training is, in most cases, an officer candidate’s first exposure to a working Air Force environment. 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 $625 for the five-week summer camp.

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 works, 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 Airport.

Introductory Flight Training:
The Introductory Flight Training (IFT) is a program made available to pilot candidates after the summer of their junior year. This program is designed to give flying experience to those individuals who do not possess a private pilot license. The purpose of this program is to increase the success rate of officers entering Joint Specialized undergraduate Pilot Training (JSUPT). Pilot candidates will receive ground school and 50 hours of flying time from a flight instruction program operating in accordance with Federal Aviation Regulations. At the completion of the program the student will have the opportunity to receive a private pilot license.

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 to an Air Force base where they spend the day, remain on base overnight, and return to campus the following day.

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 Parachute Freefall and Glider Instruction, are also available to selected volunteer officer candidates during the summer.

INTRODUCTION
Undergraduates majoring in biology & biotechnology have the opportunity to gain extensive knowledge of the scientific basis of biological investigation ranging from biological macromolecules, through genes and cells, to organisms and their interactions with the environment. Students also choose experiences in hands-on laboratory and field techniques in aspects of modern biology, including cell and molecular biology, bioprocess, recombinant DNA methods, microbiology, physiology, and environmental biology. Opportunities also exist to pursue practical exposure to methods of computational biology, including bioinformatics and simulation modeling. Students who major in biology & biotechnology will be uniquely qualified for positions in academic, industrial or governmental research facilities, or for further studies in graduate or professional (medical, dental, veterinary) schools.

MISSION STATEMENT
The Department of Biology and Biotechnology will make scholarly scientific and technological advances and discoveries that address the changing needs of society. The Department’s mission is to prepare well-educated scientists who approach problems with creativity and flexibility. A key element in the development of these scientists is participation in the process of scientific discovery.
ACADEMIC GOALS
1. BB graduates have mastered a broad range of basic lab skills to biology and biotechnology.
2. BB graduates have mastered applied research skills at an advanced level in at least one area of biology and biotechnology.
3. BB graduates know and understand a broad range of basic biological concepts, and can apply and analyze these in at least one specialty area.
4. BB graduates are able to generate hypotheses, design approaches to test them, and interpret the data for those tests to reach valid conclusions.
5. BB graduates have developed the ability to place their own work in a larger scientific context.
6. BB graduates have developed oral and written communication skills relevant to professional positions in biology and biotechnology.
7. BB graduates can find, read, and critically evaluate the original scientific literature.
8. BB graduates possess skills necessary for life-long professional learning.
9. BB graduates can function effectively as members of a team.
10. BB graduates demonstrate adherence to accepted standards of professional and ethical behavior.

BIOLOGY & BIOTECHNOLOGY
Biology, simply stated, is the study of living organisms. Biotechnology is broadly defined as the use of organism and their components for the manufacture or modification of products, the alteration of animals and plants, and the adaptation of microorganisms to specific tasks. Biotechnology is as old as winemaking, farming, and animal husbandry and as new as methods of DNA recombination. In modern context, biotechnology is further defined as the use of technological research tools in deciphering questions about living organisms, and the application of engineering principles and methods to these questions.

Students may choose to pursue a generalist degree in biology & biotechnology, or to structure their academic programs within any of five concentrations: bioprocess, cell & molecular biology and genetics, computational biology, ecology and environmental biology, or organismal biology. These concentrations provide not only guidelines for course choices within the department, but also include educational opportunities that cross academic disciplines.

UNDERGRADUATE RESEARCH PROJECTS
The biology & 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 traditional worked with WPI, such as the University of Massachusetts Medical School, the Worcester Biotechnology Research Park, Tufts School of Veterinary Medicine, Woods Hole Marine Biological Laboratories, and the Massachusetts Audubon Society. 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 on-going research activities of the faculty. The department faculty must be consulted for approval of a project before student work begins.

BASIC CURRICULUM
Programs within the department provide a broad base of scientific information and experience with in-depth laboratory study in personally selected areas of biology and biotechnology. With your faculty advisor, you will plan your own unique program, which will include a variety of course work and research experiences.

A modern biology also needs exposure to other sciences and mathematics in order to process experimental data, solve problems, and understand the chemical and physical rules under which biological systems operate. Most students should therefore take general chemistry, organic chemistry, biochemistry, physics, calculus and statistics to round out their scientific education.

GUIDELINES FOR SELECTION OF BB COURSES
Introductory survey courses are numbered at the 1000-level. Courses at the 2000-level introduce basic concepts in a defined area. Advanced subjects taught mostly from texts are at the 3000-level, and courses at the 4000-level are taught using mostly the original scientific literature.

Program Distribution Requirements for the Biology and Biotechnology Major

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Minimum Units</th>
</tr>
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<tbody>
<tr>
<td>BIOLOGY AND BIOTECHNOLOGY</td>
<td>5</td>
</tr>
<tr>
<td>1. Mathematical Science, Physics, Computer Science, Engineering</td>
<td>2</td>
</tr>
<tr>
<td>2. Chemistry</td>
<td>5/3</td>
</tr>
<tr>
<td>3. BB 1000/2000-level</td>
<td>4/3</td>
</tr>
<tr>
<td>4. BB Laboratory Fundamentals (see Note 1)</td>
<td>1/3</td>
</tr>
<tr>
<td>5. Other Laboratory Experience (see Note 2)</td>
<td>2/3</td>
</tr>
<tr>
<td>6. BB 3000/4000-level (see Note 3)</td>
<td>5/3</td>
</tr>
<tr>
<td>7. Related Courses (see Note 4)</td>
<td>4/3</td>
</tr>
<tr>
<td>8. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTES:
2. Chosen from among BB 3000/4000 Laboratories or from Laboratory Experience List for all Concentrations.
3. In certain cases 500-level courses are appropriate for undergraduate credit with explicit permission of the Instructor.
4. Chosen from among the Related Courses Lists for all Concentrations.
BIOLOGY AND BIOTECHNOLOGY

WITH CONCENTRATIONS

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematical Science, Physics,</td>
<td>2</td>
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<tr>
<td>Computer Science, Engineering</td>
<td></td>
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<tr>
<td>2. Chemistry</td>
<td>5/3</td>
</tr>
<tr>
<td>3. BB 1000/2000-level</td>
<td>4/3</td>
</tr>
<tr>
<td>4. BB Laboratory Fundamentals (see Note 2)</td>
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</tr>
<tr>
<td>7. Related Courses (see Note 5)</td>
<td>4/3</td>
</tr>
<tr>
<td>8. MQP (see Note 6)</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTES:

1. Students pursuing a Concentration must fulfill all requirements for that Concentration. Specific rules and course lists for each Concentration follow. No course may count in more than one category, including University and departmental distribution requirements.

2. Chosen from among 1000- and 2000-level options, currently BB 2940 and BB 2950.

3. Chosen from among BB 3000/4000 Laboratories or from Laboratory Experience List. Appropriate courses are suggested for each Concentration.

4. Of these 5/3 Units, 2/3 must come from the appropriate approved Concentration List. In certain cases 500-level courses are appropriate for undergraduate credit with explicit permission of the Instructor.

5. Chosen from among courses specified within each concentration’s Related Courses List.

6. Must be approved by the MQP advisor of record as appropriate for the Concentration.

APPROVED COURSES FOR THE CONCENTRATION IN BIOPROCESS

OTHER LABORATORY EXPERIENCE

Students concentrating in Bioprocess MUST choose at least 2/3 Units of Laboratory-oriented coursework. These courses may be chosen from any combination of Biology and Biotechnology 3000- or 4000-level courses and Approved “Other Laboratory Options” below.

Suggested Courses:

BB 3513 Cell Culture Techniques for Animal Cells
BB 3516 Separation Techniques in Biotechnology
BB 3517 Fermentation
BB 3519 Protein Purification

Other Laboratory Options:

BB 3511 Nerve and Muscle Physiology
BB 3512 Molecular Genetics Lab
BB 3514 Circulatory and Respiratory Physiology
BB 3518 Molecular Biology
BB 3520 Recombinant DNA Technology
BE 562 Small Animal Surgery
CE 4060 Environmental Engineering Laboratory
CE 4061 Hydrology
CH 4150 Experimental Biochemistry
GE 2341 Geology

BB 3000/4000-LEVEL

Students concentrating in Bioprocess MUST choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below.

BB 3055 Microbial Physiology
BB 4008 Cell Culture Theory and Applications
BB 4070 Separation of Biological Molecules (not available for credit in addition to BB560)
BB 505 Fermentation Biology
BB 509 Scale-up of Bioprocessing
BB 560 Separation of Biological Molecules (not available for credit in addition to BB4070)

RELATED COURSES

Students concentrating in Bioprocess must choose AT LEAST 1/3 Unit in Chemistry from the list below, but MAY NOT COUNT more than 2/3 Units in Chemistry toward this Concentration requirement. Remaining Units must be selected from “Other Courses” below:

Chemistry
CH 3510 Chemical Thermodynamics
CH 4110 Biochemistry I
CH 4120 Biochemistry II

Other Courses
CM 2011 Chemical Engineering Fundamentals
CM 2013 Applied Chemical Engineering Fundamentals
CS 1001 Introduction to Computers
CS 1005 Introduction to Programming
CS 2005 Data Structures and Programming Techniques
ES 3002 Mass Transfer

APPROVED COURSES FOR THE CONCENTRATION IN CELL & MOLECULAR BIOLOGY AND GENETICS

OTHER LABORATORY EXPERIENCE

Students concentrating in Cell & Molecular Biology and Genetics MUST choose at least 2/3 Units of Laboratory-oriented coursework. These courses may be chosen from any combination of Biology and Biotechnology 3000- or 4000-level courses and Approved “Other Laboratory Options” below.

Suggested Courses:

BB 3512 Molecular Genetics Lab
BB 3513 Cell Culture Techniques for Animal Cells
BB 3516 Separation Techniques in Biotechnology
BB 3518 Molecular Biology Lab
BB 3519 Protein Purification
BB 3520 Recombinant DNA Technology
CH 4150 Experimental Biochemistry

Other Laboratory Options:

BB 3511 Nerve and Muscle Physiology
BB 3514 Circulatory and Respiratory Physiology
BB 3517 Fermentation
BE 562 Small Animal Surgery
CE 4060 Environmental Engineering Laboratory
CE 4061 Hydrology
GE 2341 Geology
BB 3000/4000-LEVEL
Students concentrating in Cell & Molecular Biology and Genetics must choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below.
BB 3055 Microbial Physiology
BB 3080 Neurobiology
BB 3620 Developmental Biology
BB 3920 Immunology
BB 4008 Cell Culture Theory and Applications
BB 4010 Advanced Molecular Genetics
BB 4065 Virology
BB 4550 Advanced Cell Biology
BB 4910 Molecular Biology
BB 4955 Recombinant DNA

RELATED COURSES
Students concentrating in Cell & Molecular Biology and Genetics must choose at least 2/3 Units in Chemistry from the list below. Remaining Units may be selected either from Chemistry options below, or from “Other Courses” below.
Chemistry
CH 2330 Organic III
CH 4110 Biochemistry I
CH 4120 Biochemistry II
CH 4150 Experimental Biochemistry
CH 4160 Membrane Biophysics
CH 4910 Regulation of Gene Expression
Other Courses
BB 3055 Microbial Physiology
BB 3080 Neurobiology
BB 3620 Developmental Biology
BB 3920 Immunology
BB 4008 Cell Culture Theory and Applications
BB 4010 Advanced Molecular Genetics
BB 4065 Virology
BB 4550 Advanced Cell Biology
BB 4910 Molecular Biology
BB 4955 Recombinant DNA

APPROVED COURSES FOR THE CONCENTRATION IN COMPUTATIONAL BIOLOGY

OTHER LABORATORY EXPERIENCE
Students concentrating in Computational Biology MUST choose at least 2/3 Units of Laboratory-oriented coursework. These courses may be chosen from any combination of Biology and Biotechnology 3000- or 4000-level courses and Approved “Other Laboratory Options” below.

Suggested Courses:
BB 3511 Nerve and Muscle Physiology
BB 3512 Molecular Genetics Lab
BB 3514 Circulatory and Respiratory Physiology
BB 3518 Molecular Biology Lab
BB 3520 Recombinant DNA Technology
CE 4061 Hydrology

Other Laboratory Options:
BB 3513 Cell Culture Techniques for Animal Cells
BB 3516 Separation Techniques in Biotechnology
BB 3517 Fermentation
BB 3519 Protein Purification
BE 562 Small Animal Surgery
CE 4060 Environmental Engineering Laboratory
CH 4150 Experimental Biochemistry
GE 2341 Geology

BB 3000/4000-LEVEL
Students concentrating in Computational Biology must choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below:
BB 3020 Computational Biology
BB 3040 Experimental Design and Data Analysis
BB 444X Bioinformatics
BB 542 Ecological Simulation

RELATED COURSES
Students concentrating in Computational Biology must choose at least 4/3 Units from among “Approved Courses” below:
Approved Courses
BB 3020 Computational Biology
BB 3040 Experimental Design and Data Analysis
BB 444X Bioinformatics
BB 542 Ecological Simulation
CH 4130 Biochemistry III
CS 2005 Data Structures and Programming Techniques
CS 2022/
MA 2201 Discrete Mathematics
CS 2135 Programming Language Concepts
CS 2136 Paradigms of Computation
CS 2223 Algorithms
CS 3041 Human-Computer Interaction
CS 4031 Numerical Analysis I
CS 4120 Analysis of Algorithms
MA 2051 Ordinary Differential Equations
MA 2271 Graph Theory
MA 2273 Combinatorics
MA 2431 Mathematical Modeling with ODE
MA 2631 Probability
MA 3231 Linear Programming
MA 3233 Discrete Optimization
MA 3613 Probability for Applications

APPROVED COURSES FOR THE CONCENTRATION IN ECOLOGY AND ENVIRONMENTAL BIOLOGY

OTHER LABORATORY EXPERIENCE
Students concentrating in Ecology and Environmental Biology MUST choose at least 2/3 Units of Laboratory-oriented coursework. These courses may be chosen from any combination of Biology and Biotechnology 3000- or 4000-level courses and Approved “Other Laboratory Options” below.

Suggested Courses:
BB 3511 Nerve and Muscle Physiology
BB 3514 Circulatory and Respiratory Physiology
BE 562 Small Animal Surgery
CE 4060 Environmental Engineering Laboratory
CE 4061 Hydrology
GE 2341 Geology

Other Laboratory Options:
BB 3512 Molecular Genetics Lab
BB 3513 Cell Culture Techniques for Animal Cells
BB 3516 Separation Techniques in Biotechnology
BB 3517 Fermentation
BB 3518 Molecular Biology Lab
BB 3519 Protein Purification
BB 3520 Recombinant DNA Technology
BE 562 Small Animal Surgery
CE 4060 Environmental Engineering Laboratory
CH 4150 Experimental Biochemistry
BB 3000/4000-LEVEL
Students concentrating in Ecology and Environmental Biology must choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below.
BB 3055 Microbial Physiology
BB 3110 Animal Physiology
BB 3120 Plant Physiology and Cell Culture
BB 3140 Evolution: Pattern and Process
BB 3160 Behavioral Ecology
BB 4140 Ecological Management
BB 4150 Population and Community Ecology
BB 542 Ecological Simulation

RELATED COURSES
Students concentrating in Ecology and Environmental Biology must choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below.
BB 3055 Microbial Physiology
BB 3110 Animal Physiology
BB 3120 Plant Physiology and Cell Culture
BB 3140 Evolution: Pattern and Process
BB 3160 Behavioral Ecology
BB 4140 Ecological Management
BB 4150 Population and Community Ecology
BB 542 Ecological Simulation

BB 3000/4000-LEVEL
Students concentrating in Organismal Biology must choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below.
BB 3055 Microbial Physiology
BB 3110 Animal Physiology
BB 3120 Plant Physiology and Cell Culture
BB 3140 Evolution: Pattern and Process
BB 3160 Behavioral Ecology
BB 3170 Plant Morphology and Development
BB 3620 Developmental Biology

RELATED COURSES
Students concentrating in Organismal Biology must choose 5/3 Units of course work in Biology and Biotechnology at the 3000 or 4000 level. At least 2/3 Units MUST come from the Approved Courses below.
BB 3055 Microbial Physiology
BB 3110 Animal Physiology
BB 3120 Plant Physiology and Cell Culture
BB 3140 Evolution: Pattern and Process
BB 3160 Behavioral Ecology
BB 3170 Plant Morphology and Development
BB 3620 Developmental Biology

APPROVED COURSES FOR THE CONCENTRATION IN ORGANISMAL BIOLOGY

OTHER LABORATORY EXPERIENCE
Students concentrating in Organismal Biology MUST choose at least 2/3 Units of Laboratory-oriented coursework. These courses may be chosen from any combination of Biology and Biotechnology 3000- or 4000-level courses and Approved “Other Laboratory Options” below.
Suggested Courses:
BB 3511 Nerve and Muscle Physiology
BB 3513 Cell Culture Techniques for Animal Cells
BB 3514 Circulatory and Respiratory Physiology
BB 3517 Fermentation
BE 562 Small Animal Surgery
CH 4150 Experimental Biochemistry

Other Laboratory Options:
BB 3512 Molecular Genetics Lab
BB 3516 Separation Techniques for Biotechnology
BB 3518 Molecular Biology
BB 3519 Protein Purification
BB 3520 Recombinant DNA Technology
CE 4060 Environmental Engineering Laboratory
CE 4061 Hydrology
GE 2341 Geology

MISSION STATEMENT
The Biomedical Engineering department prepares technically competent engineers who aspire to contribute their knowledge and talents to the enhancement of health care. Through project-oriented education consistent with the philosophy of WPI, students learn how to apply broad engineering and basic science skills to solve biomedical engineering problems.
PROGRAM EDUCATIONAL OBJECTIVES
The biomedical engineering department educational objectives are to prepare effective professionals who possess fundamental knowledge of engineering and basic science and can apply these principles to the solution of problems in biology and medicine for the enhancement of health care. Through a balanced curriculum, which closely embraces the WPI educational philosophy, we provide an education that prepares students to work effectively in teams and to engage in a lifetime of professionalism and learning.

EDUCATIONAL OUTCOMES
Students graduating from this program will be able to demonstrate:
1. A proficiency in the fundamental use of mathematics and science principles including modern engineering principles to identify, formulate and solve contemporary biomedical engineering problems.
2. An ability to design, conduct, analyze and interpret data from basic experiments on living and non-living systems.
3. An ability to function on multi-disciplinary teams.
4. Effective oral and written communication skills.
5. An understanding of the impact of biomedical engineering solutions in a global/societal context.
6. An ability to engage in life-long learning.
7. An understanding of professional and ethical responsibilities.

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 the 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 20.

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
4. Analyzing, designing, and implementing improved health-care 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:
- design and development of an artificial heart prosthesis;
- development of tissue compatible materials;
- design of an implantable power source;
- design of waste heat removal systems;
- 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 as well as at the affiliated institutions previously listed.

COMBINED B.S./MASTER'S DEGREE PROGRAM
A combined B.S./Master's program in Biomedical Engineering is available for qualified students who wish to accelerate their graduate work.

Graduate programs (Master of Science or Master of Engineering) are available in 1) Biomedical Engineering for those students interested in the application of engineering to research and development in biology and medicine; 2) Clinical Engineering for those students interested in performing engineering in hospitals or other clinical environments. The department also offers a doctoral program in Biomedical Engineering.
### BIOMEDICAL ENGINEERING PROGRAM CHART*

<table>
<thead>
<tr>
<th>Mathematics &amp; Science</th>
<th>Social Science</th>
<th>Sufficienty</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA 1021: Calculus I</td>
<td>2 Biology courses. Suggested:</td>
<td>See Undergraduate Catalog</td>
</tr>
<tr>
<td>MA 1022: Calculus II</td>
<td>BB 3110: Animal Physiology &amp; BB 2130: Anatomy</td>
<td></td>
</tr>
<tr>
<td>MA 1023: Calculus III</td>
<td>MA 1024: Calculus IV</td>
<td></td>
</tr>
<tr>
<td>MA 2051: Diff. Equat.</td>
<td>CH 1010: Chem. I &amp; CH 1020: Chem. II</td>
<td></td>
</tr>
<tr>
<td>MA 2611: Statistics I</td>
<td>2 Physics courses. Suggested:</td>
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<tr>
<td></td>
<td>PH 1110: Mechanics &amp; PH 1120: Electricity</td>
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</table>

<table>
<thead>
<tr>
<th>Basic Requirements (19/3 units)</th>
<th>Interest Areas, Elective Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Units, with at least two 4000 level courses</td>
<td>Choose one each from EE*, CS, material science &amp; physiology lab.</td>
</tr>
<tr>
<td></td>
<td>Suggested:</td>
</tr>
<tr>
<td></td>
<td>EE 3601: Principles of EE*</td>
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<tr>
<td></td>
<td>CS 1005: Intro. to Program in C</td>
</tr>
<tr>
<td></td>
<td>ES 2001: Intro. Material Science</td>
</tr>
<tr>
<td></td>
<td>BE 3110: Exp. Physiol. for Eng.</td>
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<thead>
<tr>
<th>Social Science</th>
<th>Sufficiency</th>
<th>IQP</th>
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<tr>
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<td>See Undergraduate Catalog</td>
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<table>
<thead>
<tr>
<th>Free Electives</th>
<th>Additional Courses</th>
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<tbody>
<tr>
<td>Be Courses</td>
<td>Choose one each from EE*, CS, material science &amp; physiology lab.</td>
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<td>Suggested:</td>
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<td></td>
<td>EE 3601: Principles of EE*</td>
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<table>
<thead>
<tr>
<th>Biological Engineering</th>
<th>Biochemical</th>
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</thead>
<tbody>
<tr>
<td>MA 1022: Calculus II</td>
<td>BE 2011: BE Design</td>
</tr>
<tr>
<td>MA 1023: Calculus III</td>
<td>BE 2021: Bioinstr. &amp; Biosensor</td>
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<tr>
<td>MA 2611: Statistics I</td>
<td>BE 4011: Bio. Signal Analysis</td>
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<tr>
<td></td>
<td>BE/ME 4606: Biofluids</td>
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<tr>
<td></td>
<td>BE/ME 4814: Biomed Materials</td>
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</tbody>
</table>

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<tr>
<td>EE 2022</td>
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<td>EE 2111</td>
<td>CM 2013</td>
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<tr>
<td>EE 2201</td>
<td>CH 3510</td>
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<tr>
<td>EE 2311</td>
<td>Biomaterials</td>
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<tr>
<td>EE 3801</td>
<td>CM 3601</td>
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<tr>
<td>EE 3804</td>
<td>ME 2820</td>
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<td>EE 3804</td>
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<td>EE 4802</td>
<td>ES 3004</td>
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<td>EE 4902</td>
<td>Environmental</td>
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<td>EE 4902</td>
<td>CM 3910</td>
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<td>EE 4902</td>
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<td>EE 4902</td>
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<td>EE 4902</td>
<td>CM 3201</td>
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<td>EE 4902</td>
<td>CM 4401</td>
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<td>EE 4902</td>
<td>CM 4402</td>
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<td>EE 4902</td>
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<th>Interest Areas, Elective Courses</th>
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<td>CM 4402</td>
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<td></td>
<td>CM 4405</td>
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</tbody>
</table>

* Students taking the bioelectrical interest area should substitute another EE course.

** Courses listed are appropriate for most students; however, other projects, independent studies and courses may be substituted subject to the approval of the advisor and the BE Dept. Program Review Committee.
PROJECT/RESEARCH AREAS

BIOFLUIDS
Recent studies have focused on rethawing blood, mitral valve regurgitation, pressure wave propagation in the arterial tree, and the effects of fluid mechanics on atherogenesis. Projects usually involve scale models of physiological systems in coordination with medical studies at UMMS or TUSVM.

BIOMEDICAL MATERIALS
Research associated with the development, processing, and performance testing of biomaterials. Current projects include application of shape memory polymers in staples, membranes, fracture fixation devices and stents, investigation of the effects of sterilization on UHMWPE, growth of hydroxyapatite on collagenous surfaces, the development of Chitosan foams for wound dressing, tissue engineering, and orthopedic applications.

BIOMECHANICS
Emphasis is upon understanding the mechanical properties of soft tissues, bone and blood vessels, and how these properties are related to biological structure in both normal and disease states. Interactions between tissues and medical devices (orthopedic, dental) are also characterized. Human and animal motion (kinesiology) is studied.

BIOMEDICAL SENSORS AND INSTRUMENTATION
The Biosensors/Bioinstrumentation Laboratory supports a wide range of activities related to the development and testing of various invasive and noninvasive biosensors and associated bioinstrumentation. The development of biomedical sensors using microelectronic and optoelectronic techniques for measurement of biochemical variables in tissue and blood.

CARDIOPULMONARY SYSTEM PHYSIOLOGY
Emphasis is on the control of cardiovascular and respiratory systems. Of particular interest are questions concerning the mechanisms which are important in the cardiopulmonary response to exercise, organization of the central neural cardiopulmonary control system, control of upper airway muscles, and modeling of the cardiopulmonary systems.

IN-VIVO OPTICAL IMAGING
Research directed at revealing and understanding fundamental physiologic mechanisms using optical imaging techniques in mouse models. Fluorescence, phosphorescence absorption, and spectral imaging techniques are employed to probe cellular and physiologic events. Research areas include: 1) metabolic function and oxygenation in the brain; 2) role of oxygen in diabetic retinopathy; 3) physiologic studies in inbred, transgenic, and knockout mouse models; 4) 3-D in vivo imaging in neural tissues; 5) spectral imaging of neural tissues during functional activation.

LASER ANGIOPLASTY
Research involving the basic relationship between laser light energy and the response of tissue is being conducted. The long-term goal is to develop percutaneous transluminal angioplasty catheter systems.

LIGHT INTERACTION WITH BIOLOGICAL MEDIA
Research involving the propagation of light through skin, tissue, and blood. Theoretical studies of light scattering and absorption by biological media.

MAGNETIC RESONANCE IMAGING (MRI) AND SPECTROSCOPY (MRS)
Research focuses on the development of MRI/MRS techniques for the evaluation of therapeutic interventions in stroke and cancer. Diffusion-weighted MRI and perfusion MRI methods are being used to evaluate various pharmaceutical treatments for stroke. MRI and MRS methods for measuring tumor oxygenation are being used to evaluate agents that modify tumor oxygenation and thus enhance the efficacy of conventional therapies.

SURGICAL DEVICE DESIGN
Collaborations with physicians and medical device industry engineers are ongoing with the purpose of creating innovative designs in the areas of minimally invasive surgery, orthopedics, and dental implants. Interactions with the Endoscopy Research Center at UMMS has lead to symposia and research projects that address a range of issues from human factors to tissue manipulation.

TACTILE RECEPTORS
This research is focused on the study of the encoding characteristics of tactile mechanoreceptors. Efforts are focused on quantifying the specific stimulus modality these receptors are sensitive to and on modeling the responses of the receptors. Related research efforts focus on methods for analyzing the responses of neural systems that have continuous inputs and point-process outputs.

TEACHING LABORATORIES/FACILITIES
The following facilities are maintained by the Department of Biomedical Engineering to support teaching and project activities.

Bioinstrumentation and Biosignals Laboratory (SL 311)
This teaching laboratory provides the necessary equipment and supplies for the computer-based acquisition and processing of biological signals. It supports the laboratory component of our undergraduate (BE 1001, BE 3011, and BE 4101) and graduate-level (BE 523, BE 525, and BE 551) biomedical engineering courses in bioinstrumentation, biosensors, and bioelectric signals and is also available for project activities and graduate-level research. The laboratory is equipped with digital multimeters, waveform generators, power supplies, oscilloscopes, and the necessary accessories, electronic components, and data books for effective and productive hardware project development.

Biomechanical Engineering Laboratories (Higgins 1st Floor)
Maintained in cooperation with Mechanical Engineering
This laboratory complex provides experimental and computational facilities for the laboratory component of BME courses (BE 3101, BE/ME 4504, BE/ME 4606, and BE/ME 552), Major Qualifying Projects, and graduate research. Faculty associated with these facilities include Allen H. Hoffman, (ME, Lab Director), Sean S. Kohles (BME and ME), Brian J. Savilonis (ME), and Holly K. Ault (ME).

Included in this complex are the following individual laboratories:
Biomechanics/Biofluids Laboratory: provides experimental facilities in the areas of biomechanics and biofluids. The laboratory has equipment for measuring force, deformation, and kinematic variables as well as fluid flow, pressure, and velocity. The laboratory contains PC-based computational and data acquisition facilities. Biomaterials Laboratory: provides equipment facilities for the evaluation of biological tissues, biomedical materials, and surgical constructs with a focus on orthopedic and dental applications. The laboratory contains a computer controlled biaxial testing machine for use in these studies. Rehabilitation Engineering Laboratory: provides experimental facilities for the design, development, and testing of electro-mechanical assistive devices. The Assistive Technology Resource Center is part of this laboratory. Computing and Imaging Facility (SL 412) This computing facility, maintained by the College Computer Center (CCC), contains network attached PC-based personal computers for use by BME students and the general WPI community. In addition, the facility houses computer-based imaging hardware and software to support our undergraduate- (BE 4011, BE 4201) and graduate-level (BE 551) biomedical engineering courses and projects in biomedical imaging and biomedical signal processing. Multimedia support for most types of traditional and electronic presentations and demonstrations is also available in this facility through the Instructional Media Center (IMC). MQP/Projects Laboratory (SL 415) Because project work is a significant component of a WPI education, the department maintains a dedicated laboratory for Major Qualifying Projects (MQPs), Interactive Qualifying Projects (IQPs), and independent projects. The facility contains network-attached PC-based personal computers, computer-based data acquisition systems, general electronic testing equipment, biomechanical and biomaterial testing equipment, and other common laboratory equipment and supplies with which to complete MQPs, IQPs, and independent projects. Physiology Teaching Facility (SL 313) This teaching facility supports our undergraduate- (BE 3110) and graduate-level (BE 562) biomedical engineering courses in experimental physiology and small animal surgery. The laboratory and associated animal holding quarters, contains all the necessary equipment and supplies for anesthesia, surgery, and physiologic manipulation in small animals.

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 20), a biomedical engineer needs a solid background in mathematics, physical and life sciences. The distribution requirements are satisfied as follows:

<table>
<thead>
<tr>
<th>Biomedical Engineering</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics and Basic Science (see Notes 1, 2).</td>
<td>4</td>
</tr>
<tr>
<td>2. Engineering Science and Design (including the MQP) (Notes 3, 4, 5, 6).</td>
<td>19/3</td>
</tr>
</tbody>
</table>

NOTES:

1. Mathematics must include: differential and integral calculus, differential equations, and statistics.
2. Basic Science must include biology, chemistry and physics with a minimum of 2 courses in each area.
3. At least 6 courses in biomedical engineering with a minimum of 2 courses at the 4000-level.
4. Must include at least one course in electrical engineering, one course in computer science, one course in materials science, and one laboratory-based physiological system course or project.
5. At least 6 elective courses from one of the bioelectrical, biomechanical and biochemical interest areas. (See page 69.)
6. Must include 1/3 unit of Capstone Design Experience.

CHEMICAL ENGINEERING

R. DATTA, HEAD
ASSOCIATE PROFESSORS: W. M. Clark, D. DiBiasio, F. H. Ribeiro, B. E. Wyslouzil
ASSISTANT PROFESSORS: T. A. Camesamo, K. M. McNamara
ADJUNCT ASSISTANT PROFESSOR: T. Starr

GOALS

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.

OBJECTIVES

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

1. To educate in 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 citizens of society as well as of their professional community.
4. To help students become effective communicators.
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.

INTRODUCTION
Chemical engineers solve a wide variety of problems utilizing chemistry and engineering principles. Chemical engineers are vital to a broad range of material technologies such as plastic parts for automobiles, ceramic engine components, high-performance food packaging materials, nanofabrication technology, optoelectronic devices and modern construction materials. The fields of energy and transportation rely heavily on chemical engineering.

Chemical engineers have been key contributors in the development of designer gasoline to meet new product performance and emission requirements; liquid fuels from natural gas, coal, shale; batteries with high energy density; and novel energy-conversion technology such as fuel cells and solar cells. Many technologies to improve public health depend significantly on chemical engineering such as biomaterials, biomedical devices, medical diagnostics, the chemical synthesis of drugs, computer-aided drug design, the genetic engineering of therapeutic proteins, drug delivery systems and medical imaging technology. Finally, chemical engineering plays a dominant role in most environmental technologies. Examples are: atmospheric chemistry, product life cycle analysis, environmental risk and impact analysis, environmental friendly manufacturing technology and products, separation and conversion technologies for waste reduction and the cleanup of contaminated sites. Although the department strives to give all students a broad education, students can learn more in a given area of concentration by directing their course and project work to emphasize those areas.

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 XX), students wishing to receive the ABET-accredited degree designated “Chemical Engineering” must satisfy certain distribution requirements. These requirements apply to 10 units of study in the areas of mathematics, basic science, engineering science and design, and 2 units of advanced chemistry as follows:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
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</thead>
<tbody>
<tr>
<td>1. Mathematics and Basic Science (Notes 1, 2).</td>
<td>4</td>
</tr>
<tr>
<td>2. Engineering Science and Design (Notes 3, 4).</td>
<td>6</td>
</tr>
<tr>
<td>3. Advanced Chemistry (Note 5).</td>
<td>2</td>
</tr>
</tbody>
</table>

NOTES:
1. Must include differential and integral calculus and differential equations.
2. Must include 2 courses in physics.
3. Must include 1 unit of MQP, 1/3 unit of capstone design experience (e.g. CM 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.
4. Must include at least 4 units from the following list of core chemical engineering courses: CM 2011, CM 2012, CM 2013, CM 2014, ES 3004, ES 3003, ES 3002, CM 3201, CM 3501, CM 4401, CM 4402, CM 4403, CM 4404, CM 4405.
5. All CH courses qualify except CH 1010, CH 1020, and CH 1030 which are basic science. Up to 1 unit of Advanced Chemistry may be double counted as both Advanced Chemistry and Basic Science. One course of Advanced Natural Science (2000 level and above BB, PH, GE) may be substituted for one Advanced Chemistry course.

**CAPSTONE DESIGN REQUIREMENT**

Students may elect to satisfy WPI’s capstone design requirement in Chemical Engineering by either of two routes. The preferred manner for the student to satisfy this degree requirement is to successfully complete the design course, CM 4404, which by its nature is the very essence of capstone design as described by the chemical engineering professional society, AIChE. Alternatively, at least 1/3 unit of the MQP may be designated as “capstone design.” This option must be chosen at the time the student and the advisor agree to the content and scope of the project, and so noted on the student’s project registration form.

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### 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.

**REQUIREMENTS**

Concentrations within the Chemical Engineering 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. The two units of study will include at least one unit of coursework from a designated list of courses for the Concentration (a). The remaining one unit of work within the concentration area can be selected from additional courses from the designated list (b), or from the IQP, portions of the Sufficiency, or the Social Science requirement, when the course or project work supports a coherent and focused program of study in the subject area of the Concentration.

A coherent and focused program of study must be preapproved by the Department Program Review Committee. It is the student’s responsibility to develop an integrated program that satisfies WPI’s requirements and his/her own career aspirations. Therefore, students should plan their Concentration work with careful consultation of their Academic Advisor and the Program Review Committee. The Program Review Committee should be notified of plans for completing a Concentration before the student begins work on the Concentration. If IQP or Sufficiency work is to be used it must be certified as pertaining to the Concentration subject area by the IQP or Sufficiency advisor. The written certification should also state how many units (1/3, 2/3, or 1) the project advisor recommends be counted towards the Concentration.

(a) Experimental CM courses that emphasize the Concentration subject matter may also be used to fulfill this requirement.

(b) In special cases other courses may be approved by petition to the Program Review Committee.

### DESIGNATED LISTS OF COURSES

For each Concentration a minimum of one unit of coursework must be selected from the lists of courses given below. Courses in these lists can also be counted as Basic Science, Advanced Chemistry, or Engineering Science and Design to fulfill distribution requirements as indicated. Students are also reminded that one course of Advanced Natural Science (2000 level and above PH, BB, or GE) may be substituted for one Advanced Chemistry course in meeting the department’s distribution requirements. Some courses not on this list may be approved for a Concentration by petition to the Program Review Committee.

#### CHEMICAL ENGINEERING WITH BIOCHEMICAL CONCENTRATION

**Basic Science:**
- BB 2002 Microbiology
- BB 3055 Microbial Physiology
- BB 4008 Cell Culture Theory and Applications
- BB 4070 Separation of Biological Molecules
- BB 505 Fermentation Biology
- BB 507 Cell Culture
- BB 560 Separation of Biological Molecules

**Engineering Science and Design:**
- BB 509 Scale-Up of Bioprocessing
- CM 521 Biochemical Engineering
- BE 1001 Introduction to Biomedical Engineering

**Advanced Chemistry:**
- CH 4110 Biochemistry I
- CH 4120 Biochemistry II
- BB 4910 Molecular Biology/Biochemistry III
- CH 4130

**CHEMICAL ENGINEERING WITH BIOMEDICAL CONCENTRATION**

<table>
<thead>
<tr>
<th>Basic Science</th>
<th>(at most, one of these three)</th>
<th>(at most, one of these three)</th>
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<tbody>
<tr>
<td>BB 1030</td>
<td>Introduction to Biological Molecules</td>
<td>BB 3130 Anatomy</td>
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<tr>
<td>BB 2550</td>
<td>Cell Biology</td>
<td>BB 4065 Virology</td>
</tr>
<tr>
<td>BB 2940</td>
<td>Experimental Biology I</td>
<td>BB 4920 Immunology</td>
</tr>
<tr>
<td>BB 3110</td>
<td>Animal Physiology</td>
<td>BB 4920 Immunology</td>
</tr>
</tbody>
</table>

**Engineering Science and Design:**
- BE 1001 Introduction to Biomedical Engineering
- BE/ME 4504 Biomechanics
- BE/ME 4606 Biofluids
- BE/ME 4814 Biomedical Materials

**CHEMICAL ENGINEERING WITH ENVIRONMENTAL CONCENTRATION**

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

**Engineering Science and Design:**
- CM 3910 Chemical and Environmental Technology
- CM 3920 Air Quality Management
- CE 2062 Introduction to Environmental Engineering
- CE 3070 Introduction to Urban and Environmental Planning
- CE 3074 Environmental Analysis
- CE 3060 Water Treatment
- CE 3061 Wastewater Treatment
- CE 4060 Sanitary Engineering Laboratory
- CE 4061 Hydrology
- ME 3422 Environmental Analysis
CHEMICAL ENGINEERING SUGGESTED COURSE SEQUENCE

CM 2011
CM 2012
CM 2013
CM 2014
ES 3004 --> CM 3601
ES 3003 --> CM 3910
ES 3002 --> CM 3920
CM 3201 --> CM 3501
CM 4401
CM 4402
CM 4405
CM 4403
CM 4404

--- MAIN SEQUENCE
--- ELECTIVES
Areas of specialization in the department currently are:

- Adsorption
- Nucleation Phenomena
- Aerosol Dynamics
- Mass Transfer
- Biochemical Engineering
- Materials Processing in Space
- Catalysis/Deactivation
- Reaction Engineering
- Diffusion
- Separation Processes
- Environmental Engineering
- Synthetic Fuels
- Inorganic Membranes
- Thermodynamics
- Kinetics
- Waste Reduction
- Zeolites

CHEMISTRY AND BIOCHEMISTRY

J. P. DITTAMI, HEAD


ASSOCIATE PROFESSORS: D. T. Browne, W. D. Hobey

ASSISTANT PROFESSOR: J. M. Argüello, C. D. Fairchild, K. N. Wobbe

RESEARCH PROFESSOR OF CHEMISTRY: L. H. Berka

The Department of Chemistry and Biochemistry, under an academic reorganization approved by the Faculty of WPI in the Fall of 1995, offers two distinct majors, one in Chemistry covering the traditional areas of organic, inorganic, and physical chemistry, and one in the rapidly growing profession of Biochemistry. Both majors rely heavily on the molecular view of matter constantly under development by chemists. Students majoring in chemistry typically will focus their efforts on basic research, applied problem solving or design and synthesis of new materials. Biochemistry majors employ concepts developed through a molecular approach to understanding living systems. In this capacity Biochemistry majors incorporate a number of courses from the Department of Biology and Biotechnology into their plan of study.

In all program planning, students should work closely with their academic advisors not only to fulfill their personal interests, but to provide a sound professional background for a successful career in chemical engineering.

CHEMICAL ENGINEERING WITH MATERIALS CONCENTRATION

Engineering science and design:
- CM 3601 Chemical Materials Engineering
- ES 2001 Introduction to Material Science
- CM 543 Molecular Sieves
- CM 508 Catalysis and Surface Science of Materials
- ME 2820 Materials Processing
- ME 3811 Microstructure Analysis and Control
- ME 4813 Ceramics
- ME 4814 Biomedical Materials
- ME 4821 Chemistry, Properties, and Processing of Plastics
- ME 4840 Phase Transformations
- ME 4850 Thermodynamics of Materials

Advanced chemistry:
- CH 4550 Polymer Chemistry

MAJOR SUB-AREAS WITHIN DEPARTMENT

The areas of specialization normally available are closely tied to the research programs pursued by the faculty. Undergraduates can become involved in these areas to the extent they desire by properly selecting MQPs and by pursuing advanced courses or IS/Ps. The areas of specialization are as follows:

- Biochemical Engineering
- Chemical Kinetics, Catalysis, and Reaction Engineering
- Environmental Engineering
- Material Science and Engineering
- Membrane Technology
- Zeolite Technology

RECOMMENDED PROGRAM

Students who select chemical engineering or related fields will progress through the chemical engineering sequence as shown in the chart on page 74: first, by becoming familiar with the chemical engineering fundamentals; second, by studying the engineering sciences; and third, by becoming involved in chemical engineering design. In addition, specialized science and technology studies are recommended. This progress can be achieved by judicious selection of courses, projects, and IS/Ps.

In all program planning, students should work closely with their academic advisors not only to fulfill their personal interests, but to provide a sound professional background for a successful career in chemical engineering.

RELATED COURSES

Courses are offered either by the department faculty (CM) or by the engineering faculty under the Engineering Science (ES) label to provide the necessary background in each of the areas indicated.

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.

In all program planning, students should work closely with their academic advisors not only to fulfill their personal interests, but to provide a sound professional background for a successful career in chemical engineering.
BIOCHEMISTRY

Biochemistry is a major for students who wish to work at the interfaces of biology, chemistry and medicine. Biochemists seek to understand at the molecular level the complex chemical structures and accompanying reactions that determine biological processes such as metabolism, reproduction and growth, and their regulation through chemical messenger-receptor interactions in the immune, endocrine and nervous systems. The distribution requirements represent a balance between chemistry and biology, and between lecture and laboratory, while the overall program develops the distinct professional perspective needed to bridge molecular science to physiology.

Students who graduate with a degree in Biochemistry are well qualified for positions as professional biochemists in the pharmaceutical industry and large hospitals in areas such as drug-receptor research, bioanalytical chemistry and drug metabolism, and in the biotechnology field in jobs dealing with protein isolation, purification and modification for medical use, as well as in a variety of other employment opportunities. The program also provides excellent preparation for those who intend to further their studies in Biochemistry or related fields (e.g. Pharmacology or Immunology) at the graduate level.

Since Biochemistry embodies its distribution requirements all the technical courses needed for admission to medical, dental and veterinary schools, it is the major of choice for prehealth professionals.

Major Qualifying Projects may be carried out under the direction of a member of the Department of Chemistry and Biochemistry or any one of the Associated Faculty listed below; see their respective department descriptions for further details. MQP opportunities are also available at research centers such as the University of Massachusetts Medical Center, Tufts University School of Veterinary Medicine, and St. Vincent Hospital.

Distribution Requirements for the Biochemistry Major

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics and Physics (Note 1).</td>
<td>2</td>
</tr>
<tr>
<td>2. Chemistry and Biochemistry (Note 2).</td>
<td>4</td>
</tr>
<tr>
<td>3. Biology (Note 3).</td>
<td>1 2/3</td>
</tr>
<tr>
<td>4 Chemistry and Biochemistry / Biology Laboratory (Note 4).</td>
<td>1</td>
</tr>
<tr>
<td>5 Other Natural or Computer Science (Note 5).</td>
<td>1/3</td>
</tr>
<tr>
<td>6. MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

**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 (3000 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.

**Applicability:**
These requirements shall apply to all present and future Biochemistry majors, except when a previously enrolled student informs the Chair of the Program Review Committee for Biochemistry that (s)he wishes to follow the requirements in force at the time of his/her matriculation.

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 1001 (Term B) 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.

<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></td>
<td>BB 2550</td>
<td>HU MA</td>
<td>BB 2920</td>
<td>HU MA</td>
</tr>
<tr>
<td></td>
<td>MA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>CH 3510</td>
<td>CH 2310</td>
<td>CH 2320</td>
<td>CH 2330</td>
</tr>
<tr>
<td></td>
<td>PH HU</td>
<td>PH HU</td>
<td>PH HU</td>
<td>PH HU</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third</td>
<td>CH 4110</td>
<td>CH 4120</td>
<td>CH 4130</td>
<td>CH 4150</td>
</tr>
<tr>
<td></td>
<td>BB Lab</td>
<td>Elective</td>
<td>IGP</td>
<td>Elective</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>IGP</td>
<td>IGP</td>
<td>IGP</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td>Elective</td>
<td>Elective</td>
<td>CH 4160</td>
<td>CH 4190</td>
</tr>
<tr>
<td></td>
<td>MQP</td>
<td>Elective</td>
<td>MQP</td>
<td>MQP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ASSOCIATED BIOCHEMISTRY FACULTY

CHEMISTRY

Chemistry is a fundamental science dedicated to discovering new knowledge about the properties, structure, and reactivity of various forms of matter. The knowledge gained through fundamental scientific study allows us to understand our world more thoroughly and provides the basis for future technology.

In addition to its own intrinsic value, chemistry has an important bearing on many other areas, including materials, biology, medicine, electronics, and even psychology. Chemical science is inherently experimental, but experiments are carried out within a theoretical framework that helps make sense out of the data and also points the way to new, fruitful areas for investigation.
Chemistry graduates go on to graduate school, medical school, or into industry, government or hospital laboratories, or teaching. Chemistry provides an unusually good background for a wide variety of careers which are not in fields traditionally considered chemistry, but in which the expertise of the chemist is especially important. Examples are oceanography, environmental control, materials science, biology, and mental health. Each year many of the chemistry graduates from WPI go on to graduate school fully supported by teaching assistantships or research fellowships. Others have entered medical or dental schools, having satisfied pre-medical requirements by combining biology and biotechnology courses with a chemistry major, although this goal is now more directly satisfied through the Biochemistry major. Students interested in becoming teachers have done project work that involved classroom teaching in local schools. This has been considered as practice teaching and, in combination with appropriate education courses taken through the Worcester Consortium for Higher Education, has led to the receipt of certification for teaching in Massachusetts.

Program Distribution Requirements for the Chemistry Major

The normal period of residency at WPI is 16 terms. In addition to the WPI requirements applicable to all students (see page 20), completion of a minimum of 10 units of study is required in the areas of computer science, mathematics, basic science, and related fields as follows:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics and physics</td>
<td>2-1/3</td>
</tr>
<tr>
<td>2. Chemistry</td>
<td></td>
</tr>
<tr>
<td>(Four units of chemistry courses must be above the level of general chemistry. A portion of these four units must include courses in experimental, inorganic, organic, and physical chemistry. At least 2/3 units of courses in chemistry must be at the 4000 level or higher.)</td>
<td>4</td>
</tr>
<tr>
<td>3. Distributed among the MQP, the natural and physical sciences, computer science, mathematics, and engineering activities.</td>
<td>3-2/3</td>
</tr>
</tbody>
</table>

RECOMMENDATIONS FOR STUDENTS
Chemistry as a science applies many of the concepts of physics and mathematics. This makes it desirable for students to acquire a basic background in these subjects early in their program so that use can be made of the material in the more advanced chemistry courses. The mathematics covered in MA 1021-MA 1024 is recommended for all chemists. Students may also find it desirable to take differential equations as presented in MA 2051. A physics background should include mechanics, electricity, and magnetism. Either the PH 1110 and PH 1120 or the PH 1111 and PH 1121 sequence is suggested for this material. In addition, students seeking more depth in physics are advised to take PH 1130 and PH 1140.

The subject of chemistry is divided into the areas of inorganic, organic, analytical, and physical chemistry to aid in the organization and presentation of the subject. Every chemist should have a basic background in each of these areas to serve as a foundation for specialization in any specific area. Since chemistry is basically an experimental science, familiarity with laboratory operations is important both for understanding the subject matter and for developing practical skills needed for project work. Four laboratory courses are designed to fill this need. It is recommended that they be taken in the second year, so the experience they provide can be used in project work in the remaining years.

The following sequence of courses is recommended as providing a basic chemical background in a logical and efficient manner. Specialization in particular areas of interest is best accomplished by the choice of additional courses and projects, generally taken in the third and fourth years.

<table>
<thead>
<tr>
<th>Term A</th>
<th>Term B</th>
<th>Term C</th>
<th>Term D</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST YEAR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH 1010</td>
<td>CH 1020</td>
<td>CH 1030</td>
<td>CH 1040</td>
</tr>
</tbody>
</table>

| SECOND YEAR |
| CH 2640 | CH 2310 | CH 2320 | CH 2330 |
| CH 3510 | CH 2650 | CH 2660 | CH 2670 |

| THIRD YEAR |
| CH 3550 | CH 3410 | CH 3530 |

A three-term sequence (CH 4110, CH 4120, and CH 4130) is designed to develop a sound foundation in biochemistry. Students desiring to do project work with a biochemical emphasis should plan to take this sequence during their junior year.

Since chemistry is international in its scope, the ability to consult publications in foreign languages is very useful. German, French, and Russian are most frequently used in this way. Some training in one or more of these languages is strongly recommended. Since most graduate programs include some foreign language requirements, this is especially desirable for students planning to continue in advanced programs.

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.
Some students, particularly those interested in biochemistry, choose to do their Major Qualifying Projects at off-campus laboratories. Biochemistry projects have recently been completed at:

- University of Massachusetts Medical Center
- St. Vincent Hospital

Chemistry and biochemistry faculty participate in a range of IQP activities, as well as provide expertise in their own discipline. Their IQPs have involved students from all disciplines. Some recent examples of IQPs supervised by chemistry and biochemistry faculty include:

- Soviet science fiction
- Teaching science in the public schools
- Physical environment, human thought, and creativity
- Heavy metal pollution in the Nashua River
- Health effects of radon in Worcester
- Nanotechnology and society

INFORMATION FOR NONMAJORS

Chemistry as a basic science should be a part of the fundamental background for any science or technological career. The four-course CH 1010-1040 sequence is recommended to satisfy this need.

Many students, particularly those interested in physics, chemical engineering, biology, biotechnology, or medicine, should take more advanced courses beyond the introductory sequence. The organic sequence, CH 2310, CH 2320, CH 2330, and CH 2360, is important for students of biology and biotechnology and those dealing with plastics and polymers. Those considering medical schools must at a minimum take CH 2310, CH 2320, and CH 2360 in order to satisfy medical school entrance requirements.

Other advanced chemistry courses will be appropriate as they relate to the student’s areas of interest. Advice from members of the chemistry staff and the student’s academic advisor should be utilized.

ACS APPROVAL AND CERTIFICATION

The Department of Chemistry and Biochemistry and its chemistry program are approved by the American Chemical Society (ACS). Those graduates who complete a program satisfying the recommendations of the ACS are certified to the Society as having completed an acceptable program. Details about the requirements for certification are available from the department office.

**Independent Study Topics in Chemistry**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Faculty Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein Structure/Function Analysis</td>
<td>J. M. Argüello</td>
</tr>
<tr>
<td>Studies on Na+/K+ ATPase</td>
<td>J. M. Argüello</td>
</tr>
<tr>
<td>Chemistry of Coal and Carbon</td>
<td>H. Beall</td>
</tr>
<tr>
<td>Forensic Science</td>
<td>L. H. Berka</td>
</tr>
<tr>
<td>Optical Spectroscopy</td>
<td>R. E. Connors</td>
</tr>
<tr>
<td>Photophysical Properties of Atoms and Molecules</td>
<td>R. E. Connors</td>
</tr>
<tr>
<td>Molecular Modeling</td>
<td>R. E. Connors</td>
</tr>
<tr>
<td>Natural Product Organic Synthesis</td>
<td>J. P. Dittami</td>
</tr>
<tr>
<td>Synthetic Organic Photochemistry</td>
<td>J. P. Dittami</td>
</tr>
<tr>
<td>Alkaloid Synthesis</td>
<td>J. P. Dittami</td>
</tr>
<tr>
<td>New Methods in Organic Synthesis</td>
<td>J. P. Dittami</td>
</tr>
</tbody>
</table>
Synthesis of Biologically Active and Medicinally Important Compounds J. P. Dittami
Biological Membranes W. D. Hobey
Irreversible Thermodynamics W. D. Hobey
Transition Metal Complexes of Macrocyclic Ligands N. K. Kildahl
Catalysis by Transition Metal Complexes N. K. Kildahl
Structure-Reactivity Relationships in Metal Complexes N. K. Kildahl
Solid State Chemistry N. K. Kildahl
Electrochemical Methods N. K. Kildahl
Heterocyclic Chemistry J. Pavlik
Adsorption and Chemistry on Solid Surfaces A. A. Scala
Photo- and Radiation-Chemistry A. A. Scala
Chemistry of Carbenes S. J. Weininger
Biochemistry of Plant/Pathogen Interactions K. N. Wobbe
Nucleic Acid Biochemistry K. N. Wobbe

CIVIL AND ENVIRONMENTAL ENGINEERING

F. L. HART, HEAD
ASSISTANT PROFESSOR: J. Bergendahl, R. Mallick, J. Plummer
AFFILIATE PROFESSORS: N. Wittels

MISSION STATEMENT
The Civil and Environmental 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.

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.

INTRODUCTION
The major designated as “Civil Engineering” is the only program accredited by the Accreditation Board for Engineering and Technology (ABET) within the Department of Civil Engineering.

The broad range of work in civil and environmental engineering practice allows an individual to contribute professionally in a variety of different ways. On the one hand, the engineer may be involved in the broad scope of planning and managing the successful completion of a complex project that benefits our society. Examples of these types of projects include water resources and facilities; wastewater treatment facilities; hazardous or solid waste disposal systems; site design; buildings of all types; or transportation systems, such as highways and bridges, tunnels, mass transportation, airports, or harbor facilities. On the other hand, the engineer may wish to specialize and become expert in the professional activities associated with one of the many subdisciplines, such as structural engineering, environmental engineering, transportation engineering, geotechnical engineering, or materials engineering. You have enormous flexibility in defining your educational program at WPI, and academic planning is one of the more important activities in which you will engage. With some limitations, you may specialize in one area, or you may develop a broad educational program that involves several subdisciplines. For most students, it is important to develop a program that has a broad overall structure, and, at the same time, has the flexibility to be modified with little disruption as conditions and your growth in understanding evolve. You should work closely with your advisors to develop a program that meets WPI and ABET professional requirements, while at the same time meeting your objectives and providing opportunities for explorations and educational expansion.

In developing your educational program, it is possible, and often desirable, to construct a general civil engineering program with focus on two or more of the subdisciplines. This type of program allows maximum flexibility and employment opportunities upon graduation. It also is possible to develop a program that provides a concentration of studies in one subdiscipline with minimal breadth in related subdisciplines. Each of these types of goals has advantages and limitations from both professional and educational viewpoints. The Civil and Environmental Engineering Department advisors can provide you with a document that provides guidance and sample programs within the context of WPI and ABET requirements.

The professional career opportunities for civil engineers are many and broadly varying. Normally, it is valuable to become a registered professional engineer as early in a career as possible. The usual route to becoming a registered professional engineer involves (a) obtaining a degree from an ABET-accredited program; (b) passing the Fundamentals of Engineering Examination (FEE); (c) acquiring the necessary amount of professional level engineering experience; and (d) passing the professional engineers examina-
tion of the appropriate state licensing board. One can get the ABET accredited program in civil engineering at WPI. It is recommended that you take the Fundamentals of Engineering Examination (FEE) during the last year at WPI. This educational background should prepare you for the entry level engineering work necessary to complete the other professional registration requirements.

It is possible to enter the professional work force after receiving the BS degree. An additional opportunity that should be considered sometime before the final year is the integration of the BS with a MS degree. These degrees can be earned with five complete academic years of education. It is becoming more common to consider the MS degree as the first professional degree. Individuals who have recognized career objectives should consider this opportunity. The integration allows both graduate and undergraduate courses to be incorporated into the programs with possible reductions in costs and time. It is also possible, of course, to obtain advanced degrees in civil engineering specialty disciplines or in other fields concurrently with professional employment through a continuing education program.

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 20), 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:

<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></td>
</tr>
<tr>
<td>2. Engineering Science and Design</td>
<td></td>
</tr>
<tr>
<td>(including the MQP) (Note 3,4,5,6).*</td>
<td>6</td>
</tr>
</tbody>
</table>

Notes:
1. Mathematics must include differential and integral calculus and differential equations.
2. Must include both chemistry and physics with a minimum of two courses in either.
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 those 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 3054, CE 4046, and CE 4060. Alternatively, 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.

RECOMMENDED FUNDAMENTAL BACKGROUND

MATHEMATICS AND BASIC SCIENCE
It is essential that civil engineering students be well grounded in mathematics, the basic language of all engineers. For students with a normal secondary school background, the following courses should be taken: MA 1021, MA 1022, MA 1023, and MA 2051. At least one, and preferably several additional courses are valuable to a civil engineering education and may be selected from the following courses, depending upon the student’s interests: MA 1024, MA 2210, MA 2071, or MA 2611. MA 2210, Mathematical Methods in Decision making, in particular, is useful in working with civil engineering systems. As students progress and begin to develop a keen interest in a specific area of civil engineering, they should be prepared to seek additional mathematical support for advanced-level work. Advanced placement from high school, properly included in the WPI transcript, will be given appropriate credit.

A background in basic sciences is required. The student must include both physics and chemistry with a minimum of two courses in either. Possible basic science courses are CH 1110, PH 1120, CH 1130, CH 1010, CH 1020, CH 1030, CH 1040, GE 2341, BB 1001 and BB 2002. Advanced placement from high school, properly included in the WPI transcript, will be given appropriate credit.

ENGINEERING SCIENCE AND DESIGN
Engineering sciences have their roots in mathematics and basic sciences, but carry knowledge further toward creative application. Courses in engineering science provide a bridge between basic science and engineering practice. A student should select the engineering sciences that are appropriate for advanced professional design courses, and then fill out any additional requirements of engineering science with electives that provide a broad base for engineering practice. Consideration should be given to those engineering sciences required for the Fundamentals of Engineering Examination (FEE). At least one course must be from outside of the major area. Please note that ES 2503 and ES 3004 are regarded as civil engineering courses, and are an important part of the FEE examination. The engineering science requirement can be met by selecting a combination of courses from several disciplines. A partial listing of applicable courses from other disciplines that are useful for civil and environmental engineering students includes ES 3001, EE 3601, and FP 3070. Civil engineering courses that are considered engineering science include: CE 2000, CE 2001, CE 2002, CE 2020, CE 3024, CE 3026, CE 3041, and CE 4007. In addition, other courses designated CE have a significant engineering science component. Students can obtain information on these courses in consultation with their academic advisors.
CIVIL AND ENVIRONMENTAL ENGINEERING PROGRAM CHART

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.

### MATHEMATICS | SCIENCE †
---|---
4 Units Required |  
MA1020/1021* | CH 1010
MA 1022* | CH 1020
MA 1023* | CH 1030
MA 1024 | PH 1110
MA 2051* | PH 1120
MA 2071 | PH 1130
MA 2210 | BB 1001
MA 2611 | GE 2341

**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, and differential equations.
- Science: Must include both chemistry and physics with a minimum of two courses in either.

### 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></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Courses</td>
<td>CE 3030, ES 2503 (1), ES 3001 (1,2), EE 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>
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</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>
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<tr>
<td>Depth</td>
<td>CE 2002</td>
<td>CE 3044</td>
<td>CE 3060</td>
<td>CE 3074</td>
<td>CE 3051</td>
<td>CE 3021</td>
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<td></td>
<td>CE 3008</td>
<td>CE 4048</td>
<td>CE 3062</td>
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<td>CE 3023</td>
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<td></td>
<td>CE 3026 (3)</td>
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<td>CE 4060 (3)</td>
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<td>CE 4007</td>
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<td>CE 4061</td>
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<td>CE 4017</td>
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</tbody>
</table>

| MQP | 1 Unit Emphasizing Design (in area of choice) |
|     | Should be completed in senior year and meet capstone design requirement. |

**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

<table>
<thead>
<tr>
<th>Social Science</th>
<th>2/3 Units</th>
</tr>
</thead>
<tbody>
<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>

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| Mathematics | SCIENCE † |
---|---|
| 4 Units Required |  
MA1020/1021* | CH 1010
MA 1022* | CH 1020
MA 1023* | CH 1030
MA 1024 | PH 1110
MA 2051* | PH 1120
MA 2071 | PH 1130
MA 2210 | BB 1001
MA 2611 | GE 2341

**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, and differential equations.
- Science: Must include both chemistry and physics with a minimum of two courses in either.

### 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></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Courses</td>
<td>CE 3030, ES 2503 (1), ES 3001 (1,2), EE 3601 (1,2)</td>
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</table>

<table>
<thead>
<tr>
<th>Area (4,5)</th>
<th>Structural</th>
<th>Geotechnical</th>
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<tr>
<td>Breadth</td>
<td>CE 3010</td>
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<td>CE 3059</td>
<td>CE 3070</td>
<td>CE 3050</td>
<td>CE 3020 (1)</td>
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<tr>
<td>Depth</td>
<td>CE 2002</td>
<td>CE 3044</td>
<td>CE 3060</td>
<td>CE 3074</td>
<td>CE 3051</td>
<td>CE 3021</td>
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<td>CE 4017</td>
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</tr>
</tbody>
</table>

| MQP | 1 Unit Emphasizing Design (in area of choice) |
|     | Should be completed in senior year and meet capstone design requirement. |

**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.
Engineering design is the process of devising a system, component or process to meet desired needs. It is a decision-making process (often iterative) to convert resources to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. With the exception of those CE courses designated engineering science, all other CE courses are design courses or have a significant design component. Students can obtain information on these courses in consultation with their academic advisor. At least two units of engineering design consisting of appropriate civil engineering courses and the MQP are required as part of the ABET six-unit engineering science and design distribution requirement.

**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 3010, CE 3006, CE 3008, CE 3044, CE 3026, CE 4046, CE 4048 and CE 4007. 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 3059, CE 3050 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 4048, 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 AND URBAN DESIGN**

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 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, CE 3054 and CE 305X.

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 design of a field permeameter for pavements, development of a mix design system for recycled pavement mixes, 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.

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, CE 4048, 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, CE 3026, and CE 4024 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, CE 3030, and CE 4024. 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.

MASTER BUILDER PROGRAM

INTRODUCTION
The civil engineering practice is undergoing significant, rapid and revolutionary changes, demanding a much higher level of knowledge and experience of new engineers than in previous generations. Today engineers must have skills in computer applications, information technology, management, communications and foreign languages, as well as fundamental engineering skills. They must also grasp the political economic and social implications of projects. Engineers must have an increased depth of knowledge of specialty areas and keep up with technological advances in methods and materials. A master’s degree may become soon the first recognized professional degree leading to professional licensing.

The Master Builder Program is a new Masters of Engineering program created by the Department of Civil and Environmental Engineering to respond to the needs of the profession for the 21st Century. It has been designed within the context of WPI’s project-based education and teamwork. It is available through the combined-degree program for those undergraduate students in the civil and environmental department that wish to accelerate their graduate work by careful development of their undergraduate plan of study leading to a B.S. degree and a M.E. degree in five years. The combined-degree requires 16 units for the completion of the B.S. degree. However, students can apply 12 credits counted toward the master’s degree to be counted toward the bachelor’s degree.

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 bachelors of science and master of engineering degree in civil and environmental in five years.

GRADUATE INTERNSHIPS AND CO-OP PROGRAM
A unique graduate internship program is available, allowing students to gain important clinical experiences in a practical engineering and research environments. Students are able to earn income, alternating work and on-campus classroom and laboratory activities.

PROJECTS
A great variety of projects are available to civil and environmental engineering students. Students should select project topics which are related to their subarea of emphasis. Project work is an extremely important part of civil engineering education, and the WPI Plan provides an excellent opportunity to strengthen this aspect of undergraduate education. Project activities are a combination of design, sponsored research, laboratory investigations, field work, and internship activities with governmental agencies and private industry. Students may become involved in project work at an early stage of the education program, and should have some Major Qualifying Project activity either under way or well in mind by the end of the junior year. The objectives of such work should include the development of the student’s ability to analyze comprehensive situations, consider alternative solutions, define key problems, pick out major variables, and estimate orders of magnitude for reaching decisions. A major objective is the development of sound judgment and skill, incorporating engineering economics and social factors into problem solving.
Each civil engineering student must complete a capstone design experience which draws on past course work, involves significant engineering design, and relates to the practice of civil engineering. Normally, this will be accomplished as part of the MQP. At the time of registration for the MQP, the project advisor will indicate whether this project will meet the capstone requirement. If not, the advisor will provide an additional 1/3 unit of capstone design (not MQP) work to meet the requirement. Alternatively, another MQP which meets the requirement could be selected.

INFORMATION FOR NONMAJORS

Students from other departments find certain civil engineering courses to be valuable in the construction of their individual programs. The specific courses to be taken depend upon the interest of each student. CE 2000, CE 2001, CE 3010, and CE 3041 are useful if the student’s program has a need for structures and geotechnical background. CE 3059, CE 3060 and CE 3061 are good courses for students interested in water quality control. Other courses of interest to nonmajors in this field are CE 3062 and CE 4061.

In addition to courses, the Civil and Environmental Engineering Department offers project opportunities for nonmajors as part of a project team.

PROGRAM DEVELOPMENT

The development of broad goals with an advisor is an important early step in the construction of a cohesive educational program that has substantial opportunity for flexibility and changes throughout the undergraduate association at WPI. The program will include mathematics, basic sciences, social sciences, humanities and arts sufficiency, physical education, and engineering science and design. The civil engineering advisors are listed below, organized in the general areas of interests. All of the advisors are available to provide counsel for either specific or general civil engineering programs.

CIVIL ENGINEERING AREA CONSULTANTS

Structural and Geotechnical Engineering
L. Albano
R. D’Andrea
T. El-Korchi
R. Fitzgerald
P. Jayachandran

Environmental Engineering
J. Bergendahl
M. FitzPatrick
F. Hart
P. Mathisen
J. O’Shaughnessy
J. Plummer

Transportation and Urban Planning
T. El-Korchi
M. FitzPatrick
R. Mallick
M. Ray

Construction Engineering and Management
L. Albano
R. D’Andrea
R. Fitzgerald
R. Pietroforte
G. Salazar

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:

CE 1030 Fundamentals of Computers and Civil Engineering
CE 2000 Analytical Mechanics, I
CE 2001 Analytical Mechanics, II
ES 3004 Fluid Mechanics
CE 2020 Surveying
CE 3041 Soil Mechanics

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

CE 2002 Introduction to Analysis and Design
CE 3026 Materials of Construction
CE 3030 Fundamentals of Civil Engineering AutoCAD

The courses listed below are designed to develop a professional base for more advanced work in the specialty areas, as well as to provide a terminal knowledge for students who wish to select areas of concentration in other disciplines. Student programs should include as many of these courses as possible to provide a breadth of understanding across the major civil engineering disciplines.

CE 3010 Structural Engineering
CE 3020 Project Management
CE 3059 Environmental Engineering
CE 3070 Urban and Environmental Planning

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.

Construction Engineering and Management

<table>
<thead>
<tr>
<th>Category</th>
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<th>Course Title</th>
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<tbody>
<tr>
<td>II</td>
<td>CE 3021</td>
<td>Cost Estimating, Scheduling, &amp; Cost Control</td>
</tr>
<tr>
<td>II</td>
<td>CE 3022</td>
<td>Legal Aspects in Design and Construction</td>
</tr>
<tr>
<td>I</td>
<td>CE 3023</td>
<td>Architectural Engineering Systems</td>
</tr>
<tr>
<td>II</td>
<td>CE 3024</td>
<td>Control Surveying</td>
</tr>
<tr>
<td>II</td>
<td>CE 4024</td>
<td>Real Estate Development</td>
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Environmental Engineering

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<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CE 3060</td>
<td>Water Treatment</td>
<td>I</td>
</tr>
<tr>
<td>CE 3061</td>
<td>Waste Water Treatment</td>
<td>I</td>
</tr>
<tr>
<td>CE 3062</td>
<td>Hydraulics in CE</td>
<td>I</td>
</tr>
<tr>
<td>CE 4060</td>
<td>Environmental Engineering Lab</td>
<td>I</td>
</tr>
<tr>
<td>CE 4061</td>
<td>Hydrology</td>
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Geotechnical Engineering

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<tr>
<td>CE 3044</td>
<td>Foundation Engineering</td>
<td>I</td>
</tr>
<tr>
<td>CE 4046</td>
<td>Experimental Soil Mechanics</td>
<td>II</td>
</tr>
<tr>
<td>CE 4048</td>
<td>Earth Structures</td>
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Structural Engineering

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<tr>
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<th>Course Title</th>
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<tbody>
<tr>
<td>CE 3006</td>
<td>Design of Steel Structures</td>
<td>I</td>
</tr>
<tr>
<td>CE 3008</td>
<td>Design of Reinforced Concrete Structures</td>
<td>I</td>
</tr>
<tr>
<td>CE 4007</td>
<td>Matrix Analysis of Structures</td>
<td>I</td>
</tr>
<tr>
<td>CE 4017</td>
<td>Prestressed Concrete Design</td>
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Transportation and Planning

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<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CE 3050</td>
<td>Highway Engineering &amp; Planning</td>
<td>I</td>
</tr>
<tr>
<td>CE 3051</td>
<td>Introduction to Highway, Drainage, Soils, Pavement Design and Management</td>
<td>I</td>
</tr>
<tr>
<td>CE 3054</td>
<td>Asphalt Technology</td>
<td>I</td>
</tr>
<tr>
<td>CE 3070</td>
<td>Urban &amp; Environmental Planning</td>
<td>I</td>
</tr>
<tr>
<td>CE 3074</td>
<td>Environmental Analysis</td>
<td>I</td>
</tr>
<tr>
<td>CE 4071</td>
<td>Land Use Development &amp; Controls</td>
<td>I</td>
</tr>
</tbody>
</table>

**ENVIRONMENTAL ENGINEERING**

Civil/Environmental Engineering with Emphasis on Water Quality Control

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

The Department of Civil & Environmental Engineering at WPI provides courses leading to an ABET-accredited degree in Civil Engineering. Areas of emphasis include: the planning, design, construction, operation, and regulation of water quality control systems related to water supply and waste treatment. Environmental areas also include: public health, water supply, waste minimization treatment, and management. The engineering focus is in the area of large systems associated with municipal and other public projects.

At the undergraduate level, students often complete study in the areas of hydrology, hydraulics, hydrogeology, water supply, wastewater treatment, environmental analysis, and hazardous waste management. These areas are evaluated using physical, chemical, and biochemical techniques.

In addition to municipal and regional approaches covered in most courses, many MQP projects focus on industrial environmental problems. Typical problems include: ground water and soil contamination, waste minimization, water quality, biosolids, and hazardous waste management.

Students majoring in this program would follow a general curriculum in Civil and Environmental Engineering, with emphasis on the environmental engineering subarea. 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.

**COMPUTER SCIENCE**

M. HOFRI, HEAD; L. A. BECKER, ASSOCIATE HEAD

PROFESSORS: D. C. Brown, D. Finkel, M. Hofri, S. M. Selkow, M. O. Ward

PROFESSOR OF PRACTICE: M. Ciaraldi


ASSISTANT PROFESSORS: M. Claypool, I. F. Cruz, K. Fisler, G. T. Heineman, C. Ruiz, G. N. Sarkozy, M. R. Stevens

**MISSION STATEMENT AND OBJECTIVES**

The mission of the Computer Science Department at WPI is to provide outstanding education to its undergraduate and graduate students according to the principles of the WPI mission, to further scholarship in key domains of the computing sciences, and engage in activities that improve the welfare of society and promote the reputation of WPI. The department aims to maintain an environment that promotes innovative thinking; values mutual respect and diversity; encourages and supports scholarship; advocates ethical behavior; and engenders life-long learning for its community of scholars.

**INTRODUCTION**

Computer scientists should be broadly-educated individuals with a clear understanding of the natural laws and social orders that govern the world around them. Well-educated individuals in our technical society must be knowledgeable in the areas of mathematics, humanities and social science, science, and engineering. Therefore, a student’s program of study should include in-depth studies in several disciplines in addition to computer science. Broad-based education cannot be mandated by simply listing courses or topics to be studied. Instead, the WPI Plan encourages an integration of formal course work, project activity, self-study, and personal experiences. We cannot urge strongly enough that students make the very best use of the diverse educational opportunities available to them.

To be effective in business and society, computer scientists must be able to do more than design computing systems. They must relate to and communicate with people, so as to apply these systems to improving real-life situations. In recognition of the need for technical specialists who also have human-oriented skills, the WPI Plan requires a strong background in the humanities. To ensure breadth within the broad discipline of computer science and a firm grounding in mathematics and science, a student must complete the department’s program distribution requirements.

*The major designated as “Computer Science” is the only program accredited by the Computing Sciences Accreditation Board (CSAB) within the Department of Computer Science.*
**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 20) mathematics, basic science, and related fields as follows:

<table>
<thead>
<tr>
<th>COMPUTER SCIENCE</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Computer Science (including the MQP) (Notes 1, 2).</td>
<td>6</td>
</tr>
<tr>
<td>2. Mathematics (Note 2).</td>
<td>7/3</td>
</tr>
<tr>
<td>3. Basic Science and/or Engineering Science (Notes 2, 3).</td>
<td>5/3</td>
</tr>
</tbody>
</table>

**NOTES:**
1. a. Only computer science courses at the 2000-level or higher will count towards the computer science requirement.
2. 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 4123, CS 4533), Design (CS 3041, CS 3733, CS 4233), and Social Implications of Computing (CS 3043, SS 2208). (If SS 2208 is used to satisfy this requirement, it does not count as part of the 6 units of CS.)
3. 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.

2. A cross-listed course may be counted toward only one of areas 1, 2, 3, above.
3. Courses satisfying the science requirement must come from the BB, BE, CE, CH, CM, EE, 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.

*The Computer Science Department offers a second program not accredited by the CSAB and not bearing the title “Computer Science.” The distribution requirements for that program are:*
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 computer science courses at the 2000-level or higher will 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 4123, CS 4533), Design (CS 3041, CS 3733, CS 4233), and Social Implications of Computing (CS 3043, SS 2208). (If SS 2208 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. The MQP must involve the application of computer science concepts to the Application Area specified in Requirement 4.

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.

Computer science students, upon completion of their program of study, should have developed a number of areas of competence. This competence is a blend of practical skills and knowledge of applied techniques and theoretical concepts. “Core” courses in computer science provide a foundation in the areas of programming, data and file structures, computer organization and operating systems, mathematics and theoretical computer science, and the social impact of computing.

The ability to program is a major practical skill to develop. This is fundamental, of course, to the application of computers for any purpose whatsoever. Programming is not a mere synonym for coding. It includes a skillful evaluation of the problem statement, the development of an efficient algorithm and data structure for the solution of the problem, a clear specification of the algorithm and data structure, an evaluation of the cost of executing the algorithm, the actual coding, and the creation of sufficient test cases to verify the accuracy of the solution. The student must develop a strong programming ability in at least one high-level language as well as an ability to program in an assembler language.

The efficient organization of data into structures of varying complexity is an important part of the solution to most programming problems. Students must study not only the theoretical aspects of such structures but also their applications. In addition, students must become familiar with the techniques of representing various structures within the limitations imposed by the memory and languages available on the computer.

Students should have a clear understanding of the fundamental processes that occur within a general-purpose computing system. Familiarity with the operation of the hardware should be developed, as well as knowledge of the way hardware, operating systems, and user programs interact to form an effective computing system.

The theoretical aspects of computer science depend upon discrete mathematics for their description, so computer scientists should be familiar with this area of mathematics and how it relates to computer science theory.

In today’s society the computer is a tool which affects the lives of everyone. The computer scientist cannot, in good conscience, remain blissfully ignorant of the impact caused by his or her own decisions and actions. Therefore, the computer science student is urged to study the relation between individuals, society and the computer.

Majors in computer science should be familiar with material in the following areas, although students are not required to take all of these.

Previous Distribution Requirements for Computer Science and Computers with Applications Major

The above distribution requirements apply to all students whose matriculation date is after May 1, 2000. Students who matriculated prior to May 1, 2000 should consult the catalog for their year of entry or consult with their academic advisor or the Chair of the Department Distribution Review Committee.

CORE COURSES FOR MAJORS IN COMPUTER SCIENCE

**Computer Science**
- CS 1005 Introduction to Programming
- CS 1006 Object-Oriented Introduction to Programming
- CS 2005 Techniques of Programming
- CS 2011 Introduction to Machine Organization and Assembly Language
- CS 2022 Discrete Mathematics
- CS 2135 Programming Language Concepts
- CS 2136 Paradigms of Computation
- CS 2223 Algorithms
- CS 3013 Operating Systems
- CS 3041 Human-Computer Interaction
- CS 3043 Social Implications of Information Processing
- CS 3133 Foundations of Computer Science
- CS 3733 Software Engineering

**Mathematics**
- MA 1021 Calculus I
- MA 1022 Calculus II
- MA 1023 Calculus III
- MA 1024 Calculus IV
- MA 2071 Matrices and Linear Algebra I
- MA 2611 Applied Statistics I
- MA 3613 Probability
Note that other mathematics courses, such as MA 2051, may be useful background for advanced Computer Science courses.

For students who wish to improve their communication skills, the following courses are recommended: IS 1811, Writing for International Students, IS 1812, Speech for International Students, or EN 2211, Elements of Writing.

There is one noncore language course available. CS 1001, Introduction to Computers, teaches programming using FORTRAN, which has been used in engineering and scientific programming.

**ADVANCED COURSES IN COMPUTER SCIENCE**

After students have established a firm foundation in computer science, they should explore advanced topics, leading toward MQP work. Students must take at least one course from each of the following areas: Systems (CS 3013, CS 4513, CS 4514, CS 4515), Theory and Languages (CS 3133, CS 4123, CS 4533), Design (CS 3041, CS 3733, CS 4233), and Social Implications of Computing (CS 3043, SS 2208). Other 4000-level courses may be divided among these areas or concentrated in a particular area according to each student's program objectives. The diagram on page XX indicates how the material presented in each course is used by subsequent courses. Some variation in course order may occur, but the student considering taking courses out of sequence is advised to check the course descriptions for recommended background.

Listed below are several areas of computer science in which the student may wish to specialize, including some courses from other departments. These areas are meant to be illustrative; one should choose the course of study that best meets one's own needs and plans.

**Scientific Applications**
- CS 4032 Numerical Methods for Linear and Non-linear Systems
- CS 4033 Numerical Methods for Calculus and Differential Equations
- CS 4731 Computer Graphics
- MA 1021 Calculus I
- MA 1022 Calculus II
- MA 1023 Calculus III
- MA 1024 Calculus IV
- MA 2051 Ordinary Differential Equations
- MA 4231 Linear Programming
- MA 4411 Numerical Analysis of Differential Equations
- MA 3613 Probability
- PH 1110 General Physics — Mechanics
- PH 1120 General Physics — Electricity and Magnetism

**Operating Systems**
- CS 3013 Operating Systems
- CS 4513 Distributed Computing Systems
- CS 4514 Computer Networks: Architecture and Implementation
- CS 4515 Computer Architecture
- MA 2051 Ordinary Differential Equations
- MA 3613 Probability

**Human-Computer Interaction**
- CS 3013 Operating Systems
- CS 3041 Human-Computer Interaction
- CS 3043 Social Implications of Information Processing
- CS 3733 Software Engineering
- CS 4241 Webware: Computational Technology for Network Systems
- CS 4341 Introduction to Artificial Intelligence
- CS 4431 Database Systems I
- CS 4432 Database Systems II
- CS 4731 Computer Graphics

**Languages And Compilers**
- CS 3041 Human-Computer Interaction
- CS 3133 Foundations of Computer Science
- CS 3733 Software Engineering
- CS 4233 Object-Oriented Analysis and Design
- CS 4533 Techniques of Programming Language Translation

**Theoretical Computer Science**
- CS 3133 Foundations of Computer Science
- CS 4120 Analysis of Algorithms
- CS 4123 Theory of Computation
- CS 4533 Techniques of Programming Language Translation
- MA 4631 Probability and Mathematical Statistics I

**Hardware Orientation**
- CS 4515 Computer Architecture
- EE 3601 Principles of Electrical Engineering
- EE 3801 Logic Circuits
- EE 3803 Introduction to Microprocessor Systems
- EE 3815 Digital System Design with VHDL
- EE 4801 Microprocessor System Design

Students who are interested in the hardware aspects of computers, yet do not need a strong background in electronics, may omit the introductory electrical engineering courses and begin with EE 3801. Such a decision should be discussed with one's academic advisor.

**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 work may be done as an IS/P or a PQP. Areas of study or research have included language systems, computational linguistics, compilers, computer graphics, computer networks, operating systems, automata theory, computer applications in the humanities, computer economics, proving programs correct, parallel processing techniques, recursive techniques, mini and micro computer applications, time sharing systems design, managing computer installations, performance evaluation, computer-aided instruction, microprogramming applications, documentation standards, problem-oriented systems, computer science education, data communications, and data systems for social improvement. The background required of a student for independent study work depends on the particular area of study or research.

**PROJECT OPPORTUNITIES**

Off-campus qualifying projects are available at the Silicon Valley Project Center and the NASA/Goddard Space Center.

Projects are also available on campus, both to support the on-going 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.
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 conclude with one of the following, each of which provides an integrating capstone experience:

- CS 3013 Operating Systems I
- CS 3041 Human-Computer Interaction
- CS 3133 Foundations of Computer Science
- 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 4431 Database Systems I
- CS 4432 Database Systems II

Any graduate-level CS course, except for CS 501, CS 505, CS 507, or CS 590, may be followed by CS 2005. Students who develop interest in computer science after taking CS 1001 are urged to consider taking CS 1005 or CS 1006, followed by CS 2005.

Nonmajors choosing an introductory computer science course are advised to consult with their academic advisor. Also be aware that certain departments have specific recommendations for their majors.

Students who plan to make frequent use of computers in their chosen fields are urged to begin their studies with CS 1005 or CS 1006, followed by CS 2005, and should consider pursuing a minor in Computer Science. The Computer Science minor is described below.

ELECTRICAL AND COMPUTER ENGINEERING

J. A. ORR, HEAD; F. J. LOOF, ASSOCIATE HEAD
ASSISTANT PROFESSORS: M. Bromberg, D. R. Brown, E. Clancy, C. Paar, B. Sunar, N. Whitmal
PROFESSORS OF PRACTICE: R. H. Campbell

EDUCATIONAL OBJECTIVES OF THE EE PROGRAM

The electrical and computer engineering department educates future leaders of the electrical engineering profession, with a program characterized by curricular flexibility, student project work, and active involvement of students in their learning. Through a balanced, integrated electrical engineering 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.
Based on the above objectives, students will achieve the following specific educational outcomes:

1. Preparation for engineering practice, including the technical, professional, and ethical components.
2. Preparation for the future changes in electrical engineering.
3. A solid understanding of the basic principles of electrical engineering.
4. An understanding of appropriate mathematical concepts, and an ability to apply them to EE.
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 EE.
7. Demonstration of oral and written communications skills.
8. 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 electrical engineering in a societal and global context.

**Program Distribution Requirements for the Electrical Engineering Major**

The normal period of residency at WPI is 16 terms. In addition to WPI requirements applicable to all students (see page 20), students wishing to receive the ABET-accredited major designated “Electrical 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:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics and Basic Science (Notes 1, 2, 3, 4)</td>
<td>4</td>
</tr>
<tr>
<td>2. Engineering Science and Design (ES/D) (including the MQP) (Notes 5, 6, 7)</td>
<td>6</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Basic Science courses have prefixes PH, CH, BB, and GE.
2. Mathematics must include differential and integral calculus and differential equations.
3. Must include at least 1/3 chemistry and 2/3 physics or 2/3 chemistry and 1/3 physics.
4. Must include at least 7/3 units of math.
5. The six units of Engineering Science and Design must include at least two courses outside the major area and may include as many as three. All three courses must be at the 2000-level or above. One course requirement may be satisfied by ME 3601 or any course with prefix ES (other than ES 3011, ES 4012). The second course must have the prefix CS (other than CS 2022, CS 3043). If a third course is chosen that does not have the prefix EE, it must be selected from courses having the prefix BE, CE, CM, CS, (other than CS 2022, CS 3043), ES, FP, or ME.
6. Must include at least 5 units within the Electrical and Computer Engineering area (including the MQP). All courses designated EE (except EE 3601) are applicable to these 5 units. Also, courses ES 3011, ES 4012, BE 4011, and BE 4201 are applicable to these 5 units.
7. Must include 1/3 unit of Capstone Design Experience. These distribution requirements in Electrical Engineering apply to all students matriculating at WPI after May, 2000. Students who matriculated prior to May, 2000, have the option of satisfying the distribution requirements in the catalog current at the time of their matriculation.

**PLANNING A PROGRAM IN ELECTRICAL AND COMPUTER ENGINEERING**

The following information is intended for students planning programs in the major area of electrical engineering. This program is accredited by ABET and requires fulfillment of the distribution requirements described above. It is also possible to plan programs which are not ABET-accredited for students with special interests. Examples include “Electronics Design,” “Systems Engineering,” etc. However, in general it is recommended that students pursue the electrical engineering designation as it is recognized by employers and graduate schools. In addition, registration as a Professional Engineer is simplified for those students with an ABET-accredited electrical engineering program.

**MATHEMATICS**

Study of electrical and computer engineering requires a solid foundation in mathematics. For students with a typical secondary school background it is recommended that the contents of the following course sequence be mastered early in the student’s program: MA 1021, MA 1022, MA 1023, MA 1024, MA 2051, and either MA 2611 or MA 3613. Generally, these courses should be completed before the end of the sophomore year. To provide preparation for advanced undergraduate electrical and computer engineering studies (and to complete the 7/3 units mathematics portion of the distribution requirements), a selection from the following courses is recommended: MA 2071, MA 2201, MA 2251, MA 2612, MA 3255, MA 4231, MA 4291, MA 4451. Students should consult the electrical and computer engineering subdisciplines listings below and their academic advisors in selecting the most appropriate mathematics courses. Students interested in graduate studies should pay particular attention to development of a strong mathematics background.

**BASIC SCIENCES**

A thorough understanding of the principles of the basic sciences is essential to the study of electrical and computer engineering. Physics represents the foundation of electrical engineering, with chemistry also playing an important role. It is recommended that students become knowledgeable in the material of the following courses as early as possible in the first year of study: PH 1110 or PH 1111, PH 1120 or PH 1121 (Note: PH 1111 and PH 1121 are preferred if the student has the advanced mathematical background expected.
for these courses.) Additional courses recommended for consideration (although not as necessary early in the program of study) include BB1001, CH 1010, PH 1130, PH 1140. Students interested in more advanced study should consider PH 2601, PH 3301, PH 3401, PH 3504. Students interested in biomedical engineering should consider courses in biology and biotechnology. A two-course sequence in one of the basic sciences is required for the electrical engineering major; normally the physics sequence would be used to satisfy this requirement. At least one chemistry course is also required.

**COMPUTER LANGUAGES AND COMPUTER USE**

Because the computer has become an essential tool for electrical and computer engineers, it is essential that all electrical engineering students become proficient in at least one high-level language. The C language is dominant in the electrical industrial sector; it is the strongly recommended choice, along with Java. Courses CS 1005 and CS 2005 offer instruction in the C language. Students will also be expected to use various software packages in several of their EE courses, e.g., PSpice for circuit analysis, a spreadsheet program for parametric analysis, Mathcad or Matlab for symbolic manipulation and general computation, etc. Some knowledge of the theory and operation of computers is essential to many of the EE subdisciplines, and may be gained through courses such as EE 3803 and EE 4801.

Other computer science courses of particular interest to electrical and computer engineering students include CS 2223, CS 3013, CS 3733, CS 4031, CS 4513, and CS 4514.

**BREADTH IN AREAS OTHER THAN ELECTRICAL AND COMPUTER ENGINEERING**

An electrical engineer should also have some knowledge of technical areas which are outside of, but related to electrical engineering, for example, courses in thermodynamics, engineering mechanics, materials processing and computer science beyond the introductory level. The department’s distribution requirements specify that all students’ programs must include at least one such engineering science course and a computer science course. See Note 5 under the Electrical Engineering Minimum Distribution Requirements on page 91 for the complete list of appropriate courses. Students planning to become registered Professional Engineers should see the section on Fundamentals of Engineering Examination on page 219.

Economics plays a significant role in many engineering decisions; hence, it is important that electrical engineering students become knowledgeable about the basic principles of economics. The courses SS 1110, SS 1120, and MG 2850 should be considered. The economics courses listed as “SS” may also be used to satisfy the 2/3 unit social science requirement.

**CONCENTRATION IN COMPUTER ENGINEERING**

Students interested in pursuing a concentration in computer engineering can do so by completing a set of activities as described below. Successful completion results in a B.S. degree in Electrical Engineering with the designation “with concentration in Computer Engineering” noted on the transcript if requested by the student from the Registrar.

This interdisciplinary concentration requires students to develop technical competence in mathematics, basic science, and electrical engineering, with further emphasis in computer engineering, including computer system design, high level languages and operating systems. The Major Qualifying Project provides students with the opportunity to develop in-depth knowledge of some aspect of computer engineering.

In order to be eligible to receive the Computer Engineering designation on their transcripts, students need to satisfy the following course requirements:

- At least six computer engineering related EE or CS courses must be included in the distribution requirements, as follows:
  - At least three of the following EE courses must be included:
    - EE 3803 Introduction to Microprocessor Systems
    - EE 3815 Digital System Design with VHDL
    - EE 4801 Advanced Computer System Design
    - EE 3902 Introduction to VLSI Design
    - EE 505 Computer Architecture (or CS 4515 Computer Architecture, but not both).
  - At least two 3000 or 4000 level CS courses must be included; CS 3043, Social Implications of Information Processing, cannot be used. The following are particularly recommended:
    - CS 3013 Operating Systems
    - CS 3733 Software Engineering
    - CS 4513 Distributed Computing Systems
    - CS 4514 Computer Networks
    - CS 4515 Computer Architecture (or EE 505 Computer Architecture, but not both).
  - In addition to the above course requirements, students must complete an MQP in the computer engineering area approved by the Program Coordinator.

**FUNDAMENTALS OF ELECTRICAL AND COMPUTER ENGINEERING: GETTING STARTED**

Electrical and computer engineering is constantly growing to encompass new technologies. At its center, however, is a relatively small set of principles which forms the foundation of the profession, the understanding of which is generally recognized as essential to all electrical engineers. This background is introduced by the four “basic core” courses EE 2011, EE 2022, EE 2111, and EE 2311, and built upon by the four “advanced core” courses EE 2112, EE 2201, EE 2312, and EE 2801. Furthermore, all students are strongly encouraged to take EE 2799 well in advance of the MQP, preferably by the beginning of the junior year.

For students planning to major in electrical and computer engineering, or for students who want a broad exposure to the field to determine their major, EE 2011 and EE 2022 are recommended for C and D term of the first year. It is also possible to begin with these courses at the beginning of the second year and still graduate on time; however, in either case, at least five of the core courses should be completed by the end of the second year.
Note that although the starting course in the sequence (EE 2011) assumes no preparation beyond an interest in electrical and computer engineering, subsequent EE courses begin to rely substantially on material offered in the basic physics and mathematics courses. The recommended background for EE 2111, for example, is PH 1120 or PH 1121 and MA 2051 (may be taken concurrently).

RECOMMENDATIONS FOR TRANSFER STUDENTS

Since the EE introductory curriculum is different from the traditional program offered at many other schools, transfer students must be sure to confer with their advisor to plan their WPI program. Transfer students with no previous EE courses should begin the program in the same way as first-year students. Student with some EE transfer credit may be able to omit one or more of the introductory EE courses. Those with one or more courses in circuit theory and substantial laboratory experience should consider omitting EE 2011, and possibly one or more of the other basic core courses, but this should only be done after consultation with an academic advisor.

SUBDISCIPLINES OF ELECTRICAL AND COMPUTER ENGINEERING

It is expected that students majoring in electrical engineering will select courses so as to develop both breadth and depth in this diverse discipline. Guidance for the development of depth in eight possible subdisciplines is offered below. These subdisciplines are:

1. Aerospace Systems
2. Communication and Signal Analysis
3. Computer Engineering
4. Electromagnetics and Microwaves
5. Electronics Engineering
6. Microelectronics
7. Power Systems Engineering
8. Systems Engineering

To develop depth in one of these subdisciplines, students are advised to take the Area Courses within the subdiscipline, and to select from the Related Courses identified for that subdiscipline.

Aerospace Systems


Area Courses
EE 2312 Discrete-Time Signal and System Analysis
EE 4304 Communication Systems Engineering
EE 3305 Aerospace Avionic Systems
ES 3011 Control Engineering I

Related Courses
EE 3204 Microelectronic Circuits II
EE 3311 Principles of Communication
EE 3503 Power Electronics
EE 3801 Advanced Logic Design
EE 3803 Introduction to Microprocessor Systems
EE 4203 Communications Circuit Design
ES 4012 Control Engineering II

Communications and Signal Analysis


EE 2312 Discrete-Time Signal and System Analysis
EE 3311 Principles of Communication
EE 4304 Communication Systems Engineering

Related Courses
EE 4203 Communications Circuit Design
ES 3011 Control Engineering I
MA 2071 Matrices and Linear Algebra I
MA 3613 Probability I
MA 4291 Applicable Complex Variables

Computer Engineering


Area Courses
EE 2801 Foundations of Embedded Computer System
EE 3801 Advanced Logic Design
EE 3803 Introduction to Microprocessor Systems
EE 3815 Digital System Design with VHDL
EE 3902 Introduction to VLSI Design
EE 4801 Advanced Computer System Design
CS 2005 Techniques of Programming

Related Courses
CS 2223 Algorithms
CS 3013 Operating Systems
CS 3733 Software Engineering
CS 4031/ Numerical Analysis I
MA 3255

Electromagnetics and Microwaves

Area Consultants: Profs. Ludwig, Makarov, Nicoletti

Area Courses
EE 3113 Introduction to RF Circuit Design

Related Courses
EE 2312 Discrete-Time Signal and System Analysis
MA 4451 Boundary Value Problems
PH 3301 Electromagnetic Theory
PH 3401 Quantum Mechanics I
PH 3504 Optics

Electronics Engineering


Area Courses
EE 3204 Microelectronic Circuits II
EE 4203 Communications Circuit Design

Related Courses
EE 3503 Power Electronics
EE 3801 Advanced Logic Design
EE 3306 Audio Engineering
ES 3011 Control Engineering I

Microelectronics


Area Courses
EE 3815 Digital Systems Design with VHDL
EE 3901 Semiconductor Devices
EE 3902 Introduction to VLSI Design
EE 4902 Analog Integrated Circuit Design

Related Courses
EE 3801 Advanced Logic Design
EE 4203 Communications Circuit Design
PH 3502 Solid State Physics
Power Systems Engineering  
Area Consultants: Profs. Clements, Emanuel, Hakim

Area Courses  
EE 3501 Electrical Energy Conversion  
EE 3503 Power Electronics  
EE 4502 Analysis of Large-Scale Electric Power Systems

Related Courses  
ES 3001 The Statistical Development of Classical Thermodynamics  
ES 3011 Control Engineering I  
MG 2850 Engineering Economics  
ME 1800 Material Selection and Manufacturing Processing

Systems Engineering  

Area Courses  
ES 3011 Control Engineering I  
ES 4012 Control Engineering II

Related Courses  
CS 4031 Numerical Methods for Digital Computation  
MA 2071 Matrices and Linear Algebra I  
MA 3071 Matrices and Linear Algebra II  
MA 3613 Probability I  
MA 4231 Linear Programming

PROJECT OPPORTUNITIES

Opportunities for Major Qualifying Projects exist in all of the subareas of electrical and computer engineering; most MQPs involve two or more subareas, so students should balance depth in one or more subareas with breadth across the discipline. It is highly recommended that EE 2799 be completed well in advance of starting an MQP.

In addition to projects performed on the WPI campus, a number of off-campus project opportunities exist, including those at the NASA Goddard Space Flight Center, the Limerick, Ireland MQP Program, the Silicon Valley MQP Program, and the Copenhagen, Denmark MQP Program. In addition, sponsored projects either on or off campus can be conducted in conjunction with organizations such as Allegro, Analog Devices, Teradyne, Texas Instruments. Off-campus and sponsored project opportunities for the following academic year are advertised to students each year.

Topics for on-campus projects are developed by faculty and advertised at http://www.WPI.EDU/Academics/Projects/; students who wish to propose their own topics should contact faculty in the appropriate areas and discuss their ideas. It is possible to start a project in any term, but most projects begin in Term A of the fourth year.

Each EE student must complete a Capstone Design Experience which draws on past course work, involves significant engineering design, and relates to the practice of electrical engineering as a profession. Normally this will be accomplished as part of the MQP. At the time of registration for the MQP, the project advisor will indicate whether this project will meet the Capstone requirement. If not, the advisor will provide you with an additional 1/3 unit of Capstone Design (not MQP) work to meet the requirement. Alternatively, you could seek another MQP which itself meets the requirement.

INFORMATION FOR THOSE OTHER THAN ELECTRICAL ENGINEERING MAJORS

Students who wish to develop a background in electrical engineering are advised to consult with a professor in the electrical and computer engineering department. A basic foundation in electric circuits and electronics may be obtained by taking EE 2011, EE 2111, EE 2201, and EE 2311. A basic foundation in the elements of computer engineering may be obtained by taking EE 2011, EE 2022, EE 2801, and EE 3801. An overview of the entire field of electrical and computer engineering can be obtained by taking EE 3601.

Electrical engineering may be coupled with other areas of study to define a unique interdisciplinary program. Students contemplating such an innovative program should contact the Interdisciplinary Studies Division immediately for guidance and approval, especially with regard to the selection of a suitable MQP and arrangements for program-specific distribution requirements. See page 103 for the procedures to be followed.

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. Students in ECE should instead file for a Concentration in Computer Engineering with Prof. Looft.

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.

A. At least three of the following ECE courses must be included.
- EE 2801 Foundations of Embedded Computer Systems
- EE 3801 Advanced Logic Design
- EE 3803 Introduction to Microprocessor Systems
- EE 3815 Digital System Design with VHDL
- EE 3902 Introduction to VLSI Design
- EE 4801 Microprocessor System Design
- EE 505 Computer Architecture
B. At least three of the following CS courses must be included.

- CS 2011 Introduction to Machine Organization and Assembly Language
- CS 3013 Operating Systems
- CS 3733 Software Engineering
- CS 4513 Distributed Computing Systems
- CS 4514 Computer Networks
- CS 4515 Computer Architecture (can not be counted if EE 505 is selected)

C. Capstone Courses

The following courses may be used to satisfy the Computer Engineering minor capstone requirement:

- EE 3803, EE 3815, EE 3902, EE 4801, CS 4513, CS 4514, CS 4515.

ENVIRONMENTAL SCIENCE COURSES

In the formation of a program of study for any engineering or science student, it is important to emphasize a significant number of interdisciplinary courses which form the fundamental building blocks of so many scientific and engineering activities.

In addition to those courses in science and mathematics which are an important part of every engineer’s background at WPI, there are a number of courses containing subject matter common to a variety of disciplinary interests. These courses are known as the “engineering science group” and are often taught jointly by members of more than one department.

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.

ENVIRONMENTAL ENGINEERING

Civil/Environmental Engineering with Emphasis on Water Quality Control

Coordinators: Profs. O'Shaughnessy, Hart, Mathisen, Plummer, or Bergendahl, Civil Engineering

The Department of Civil Engineering at WPI provides courses leading to an ABET-accredited degree in Civil Engineering. Areas of concentration include the planning, design, construction, operation and regulation of water quality control systems related to water supply and waste treatment. Related issues include public health and solid waste management. The engineering focus is in the area of large systems associated with municipal and other public projects.

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

Chemical/Environmental Engineering with Emphasis on Pollution Prevention and Abatement Technology

Coordinators: Profs. Wyslouzil, Thompson, Moser, Ma, Dixon, DiBiasio, 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.

Manufacturing/Environmental Engineering with Emphasis on Environmentally-Conscious Manufacturing

Coordinator: Prof. Sisson, Manufacturing Engineering

The Manufacturing Engineering program at WPI provides a general curriculum leading to an ABET-accredited degree in manufacturing 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. One of the fastest growing research areas within manufacturing engineering is that of design for the environment and environmentally-conscious manufacturing. Since manufacturing engineering is multi-disciplinary by nature, students can join the program with interests in environmental engineering, computer science, management, and electrical or mechanical engineering, or with other interests.

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

ENVIRONMENTAL SCIENCES

Biology-Biotechnology/Environmental Sciences

Coordinators: Prof. P. Robakiewicz, Biology and Biotechnology

The department of Biology & Biotechnology offers a general curriculum leading to degrees in Biology or Biotechnology. Both degree paths offer sufficient flexibility to choose course work and project research with an emphasis on ecology or environmental biology. Environmental topics under investigation by the departmental faculty include: bioremediation, behavioral and conservation ecology, release of genetically altered organisms and micro environmental regulation of growth and development in bioreactors. Course work in marine ecology is also available off campus through a cooperative arrangement with the Marine Biological Laboratory in Woods Hole. Off campus project work in conservation ecology with the Mass. Audubon Society, and the Mass. Div. of Fisheries and Wildlife occur as demand warrants.

Students with Biology or Biotechnology degrees will be prepared for entry-level professional work, or for graduate study leading to a master’s or doctoral degree.

ENVIRONMENTAL ECONOMICS AND PUBLIC POLICY

Social Sciences and Policy Studies

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

The Department of Social Sciences and Policy Studies at WPI provides a general curriculum leading to degrees in three separate areas: Economics and Technology, Society-Technology, or Economics. Students interested in careers in environmental studies involving any of these three areas could pursue programs in SSPS, leading to careers in business, research, or government.

Students majoring in one of these three 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.

ENVIRONMENTAL STUDIES

Humanities/Environmental Studies

Coordinator: Prof. R. Gottlieb, Humanities & Arts Department

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.

Interdisciplinary Environmental Studies

Coordinator: Prof. Davis, 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):
Fire protection engineers work at the nerve centers of large corporations and oversee the design and operational firesafety of complex manufacturing facilities in multinational business networks. They also work for insurance companies, surveying major facilities, and performing research, testing, and analysis.

Fire protection engineers can be found at all levels of government, worldwide. They work for architectural and engineering firms and specialty consulting groups. Interesting jobs are available in trade associations, testing laboratories, and at colleges and universities.

WPI's one-of-a-kind fire protection engineering program offers a variety of educational opportunities to suit most every student need. These include the combined degree program through which the student may earn an undergraduate degree in one of the traditional disciplines and the master's degree in fire protection engineering in as little as five years. The master of science, and doctor of philosophy in fire protection engineering are also available.

For those interested in preparing for a career in this challenging field, we recommend obtaining a B.S. degree in one of the traditional engineering disciplines and developing the experience in solving fire-related problems through qualifying project work under the supervision of faculty from WPI's Center for Firesafety Studies. An introductory undergraduate course (FP 3070 Fundamentals of Firesafety Analysis) makes an excellent companion to the qualifying project.

For advisory information (including a free fire protection engineering careers video or CD-Rom), students may contact Prof. D. Lucht, Director of the Center for Firesafety Studies.

**COMBINED-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 B.S. 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's degree. Holders of B.S. degrees in traditional engineering or science disciplines and the master's degree in fire protection engineering enjoy extremely good versatility in the job market.

**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.

**GRADUATE INTERNSHIPS**
A unique graduate internship program is available, allowing students to gain important clinical experiences in practical fire protection engineering and research environments. Students are able to earn income, alternating work and on-campus classroom and laboratory activities.

*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.*

*If you have any questions about any of these programs, see either the coordinators as listed or Prof. Woods in the Project Center.*
INTRODUCTION

The humanities and arts promote intellectual curiosity and maturity by developing the essential skills for further study and lifelong learning. These include the ability to think critically, to write and speak clearly and persuasively, to appreciate and cultivate the literary and aesthetic arts, and to understand the rich cultural diversity of the world in the past and present. Students in the humanities and arts grapple with fundamental questions of justice, value or meaning through reading, observation, creation, interpretation, and performance. These are, in fact, the activities of the highly productive Humanities and Arts faculty, which is well regarded for research, publication and creative work. Through the humanities and arts, the faculty enable students to gain self-knowledge and to broaden cultural horizons.

The Department of Humanities and Arts offers a variety of opportunities for students to pursue personal interests. The Department offers an interdisciplinary curriculum, in which students may investigate multifaceted topics using a variety of approaches. The major or double-major in Humanities and Arts is interdisciplinary in scope (see page 102). In addition, the Humanities and Arts Sufficiency Program may culminate in a thematic project that integrates previous courses from several areas of the humanities and arts. The Sufficiency Program also might result in a theatrical or musical performance or in proficiency in a foreign language. Students should also consider unique opportunities to complete a Sufficiency Project at a Global Project Center. (For details of the Sufficiency Program, see page 51.)

The close working relationship among students and faculty in the humanities and arts at WPI promotes academic excellence, innovative thinking, and mutual respect. In short, the Humanities and Arts Department is committed to helping students develop both a knowledge of, and the 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. Such an education, we believe, provides a crucial foundation for responsible and effective participation in a complex world.

MISSION STATEMENT

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INTRODUCTION

The humanities and arts—history and architecture, drama/theatre, foreign languages, history, literature, music, philosophy, religion, and writing/rhetoric—are central to WPI’s vision of the new “liberal education.” All WPI undergraduates devote a significant portion of their academic program to the humanities and arts either through a “Humanities and Arts Sufficiency Program” or through a major, double-major, or minor in the department.

The humanities and arts promote intellectual curiosity and maturity by developing the essential skills for further study and lifelong learning. These include the ability to think critically, to write and speak clearly and persuasively, to appreciate and cultivate the literary and aesthetic arts, and to understand the rich cultural diversity of the world in the past and present. Students in the humanities and arts grapple with fundamental questions of justice, value or meaning through reading, observation, creation, interpretation, and performance. These are, in fact, the activities of the highly productive Humanities and Arts faculty, which is well regarded for research, publication and creative work. Through the humanities and arts, the faculty enable students to gain self-knowledge and to broaden cultural horizons.

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HUMANITIES AND ARTS MAJOR

The Humanities and Arts major requires six units of work, including the MQP. Students take courses from across the humanities and arts, but may choose to focus their program of study by completing a Concentration as described below.

The major or double-major in Humanities and Arts is excellent preparation for a variety of careers. Humanities and Arts graduates from WPI 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, literary and musical composition or performance.

In addition, since each Humanities and Arts major completes either a “technical sufficiency” 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.
Program Distribution Requirements for the Humanities and Arts Major

1. Humanities and Arts (including MQP) (Note 1) 6
2. Electives (Note 2) 4

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 History, German Studies, Hispanic Studies, American Studies, Environmental Studies, or Humanities Studies of Science and Technology.  
2. May be from any area except Aerospace Studies, Military Science, or Physical Education. Courses used to satisfy other degree requirements (i.e. the IQP and the Sufficiency) 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 a “technical sufficiency” 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, 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 Literature and Culture, HI 1311 Introduction to American Urban History, HI 1312 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
EN 2237 American Literature and the Environment
EN 2238 American Realism
EN 3221 New England Supernaturalism
EN 3232 The Concord Writers
EN 3233 Worcester Between the Covers: Local Writers and Their Works
EN 3224 Modern American Poetry
EN 3237 Pursuing Moby-Dick

List 3. American Politics, Law, and Policy:
SS 1301 U.S. Government
SS 1303 American Public Policy
SS 1310 Law, Courts, and Politics
SS 2121 Government Budgets and Fiscal Policy
SS 1203 Social Problems and Policy Issues
SS 2302 Science-Technology Policy
SS 2304 Governmental Decision Making and Administrative Law
SS 2310 Constitutional Law
SS 2311 Legal Regulation of the Environment
SS 3278 Technology Assessment and Impact Analysis Seminar

List 1. Designated Environmental Courses in Humanities:
AR 2113 Topics in 19th- and 20th-Century Architecture
EN 2237 American Literature and the Environment
HI 1311 Introduction to American Urban History
HI 1341 Introduction to Global History
HI 2334 European Technological Development
HI 3331 Topics in Science, Technology, and Society
HI 3333 American Technological Development
PY 2712 Social and Political Philosophy
PY 2713 Bioethics
PY 2717 Philosophy and the Environment

List 2. Related Environmental Courses in Social Sciences:
SS 2117 Environmental Economics
SS 2125 Development Economics
SS 2311 Legal Regulation of the Environment
SS 2312 International Environmental Policy
SS 2405 The Psychological Study of Environmental Issues
SS 3278 Technological Assessment and Impact Analysis Seminar

List 3. Environmental Courses in Other Areas:
BB 2040 Principles of Ecology
CM 3910 Chemical and Environmental Technology
CM 3920 Air Quality Management
CE 3059 Environmental Engineering
CE 3070 Urban and Environmental Planning
CE 3074 Environmental Analysis
ME 3422 Environmental Issues and Analysis

HUMANITIES AND ARTS WITH ENVIRONMENTAL STUDIES CONCENTRATION

This interdisciplinary concentration combines course work from the humanities and arts, social sciences, and other areas to examine environmental issues.
1. 3/3 units from List 1 (“Designated Environmental Courses in Humanities”)
2. 2/3 units from List 2 (“Related Environmental Courses in Social Sciences”). These may not include courses taken to fulfill the Social Science Requirement.
3. 1/3 units from List 3 (“Environmental Courses in Other Areas”)
4. MQP in Environmental Studies

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 2331 American Science and Technology to 1859
HI 2332 American Science and Technology from 1859
HI 2333 History of Science from 1700
HI 2334 European Technological Development
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 2327 Russia from Stalin to the Present
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.  
ID 3150 Light, Vision and Understanding and the Scientific Community  
SS 2208 The Science-Technology Debate  
SS 2302 Science-Technology Policy  
SS 2304 Governmental Decision Making and Administrative Law  
SS 2311 Legal Regulation of the Environment  
SS 2312 International Environmental Policy  
SS 3278 Technology Assessment and Impact Seminar  

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 a Sufficiency Program 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.  

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 Sufficiency. 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, 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. Fontanella (for Spanish).  

MUSIC MINOR  
The minor in Music is for students who choose to continue their studies in Music beyond the Sufficiency project 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: F. Bianchi, L. Curran, or D. Weeks, all 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 Sufficiency project 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.  

INDUSTRIAL ENGINEERING  
The Industrial Engineering major is a program of the Management Department. Please refer to page 107 for more information.  

INTERDISCIPLINARY PROGRAMS  
P. DAVIS, DEAN;  
R. F. VAZ, ASSOCIATE DEAN;  
N. MELLO, DIRECTOR OF GLOBAL OPERATIONS  
PROFESSOR: P. Davis  
ASSOCIATE PROFESSORS: H. Hakim, S. Vernon-Gerstenfeld, R. Vaz  
ADJUNCT ASSISTANT PROFESSOR: W. Jamison  
ADJUNCT INSTRUCTOR: F. Carrera  

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. Hossein Hakim 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. Paul Davis, 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 chair 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.

Examples of Interdisciplinary Programs

In recent years, students have graduated in interdisciplinary programs in the following areas:

Environmental (Water Pollution) - Civil Engineering
Environmental (Air Pollution) - Chemical Engineering
Urban and Environmental Planning - Civil Engineering

Courses for these programs are located primarily in the departments listed above. Students interested in these programs should read the appropriate departmental descriptions before consulting with the chair of the IGSD about developing an ID major.

The programs below are the established majors administered through IGSD.

Theatre and Technology

Students who wish to work toward a degree in the area of Theatre and Theatre Technology may pursue this through the Department of Humanities and Arts, Drama/Theatre and English studies, or with an individually-designed (ID) degree program through the IGSD. The growing field of theatre technology, though highly selective, offers exciting career opportunities for students who enter the workplace with a strong balance of education in both theatre and technology. To meet the demands of the constantly expanding technologies available in theatre, a new work force must develop to apply and manage this growing field. For example, a graduate must know not only how to build a scenic design, but should also be prepared to work through the design on a CAD program. Audio, previously a matter of placing speakers and pressing a button to play a pre-recorded effect, currently offers digitalized effects, surround sound, and endless opportunities to enhance a production.

The performance industry requires theatre practitioners who can understand and effectively use the new technologies; the industries which supply the arts need pioneers to design and make available affordable, user-friendly equipment for use in a wide variety of performing venues.

A Theatre and Technology program provides students with prerequisites necessary to enter challenging and innovative careers. Additionally, the program, which will emphasize literature, writing, and accomplishing sophisticated projects, can give students hands-on experience in the field through internships, IQPs, and MQPs at professional theatres and other organizations which specialize in producing technology for theatre and the performing arts.

Students who wish to discuss designing an ID program in Theatre and Technology should see one of the following faculty: Professor Susan Vick, Humanities & Arts, Administrator and Instructor of Drama/Theatre, Dean O’Donnell, Humanities & Arts, Professor Lance Schachterle, Assistant Provost, or Dean Paul Davis, IGSD.

Technical, Scientific, and Professional Communication

CO-DIRECTORS: J. Trimbur (H&A), H. Beall (CH)
ASSOCIATED FACULTY: M. Elmes (MG), K. Lemone (CS), W. Mott (H&A), R. Smith (H&A)

The program in Technical, Scientific, and Professional Communication (TSPC) is concerned with the theory, ethics, research, and practice of representing information in a variety of communication media—computer documentation, instruction manuals, hypertext, multimedia presentations, graphics, video, brochures, newsletters, public relations, scholarly writing, journalism, and literary nonfic-
tion. The goal of the TSPC program is to prepare communication professionals who can bridge the gap between scientists and engineers and the public by presenting technical information in useful and accessible ways.

The TSPC program is an interdisciplinary major that combines work in written, oral, and visual communication with a strong concentration in a scientific or technical field. In consultation with a faculty program review committee, majors design a plan of study that fulfills the distribution requirements of the program and best suits their intellectual interests and career aspirations.

The TSPC major provides excellent preparation for students interested in careers in technical and scientific communication, editing, journalism, public relations, education, and publishing and for students who intend to pursue graduate studies in fields such as communication, education, journalism, and rhetoric and composition.

MQP opportunities are available on campus and with local companies, newspapers, public agencies, and private foundations.

### Distribution Requirements

**TECHNICAL, SCIENTIFIC, AND PROFESSIONAL COMMUNICATIONS**

<table>
<thead>
<tr>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scientific and/or technical concentration (Note 1)</td>
</tr>
<tr>
<td>2. Communication concentration (Note 2)</td>
</tr>
<tr>
<td>3. MQP</td>
</tr>
</tbody>
</table>

**NOTES:**

1. The student’s scientific and/or technical concentration must be a plan of study with a clear underlying rationale in mathematics, basic science, computer science, engineering, and/or management. Depending on the student’s intellectual interests and professional goals, the plan of study may lead to in-depth mastery of an area of science or technology or it may provide the student with a broad overview.

2. The Communication concentration consists of 1 unit in each of 3 categories of courses. Courses taken to fulfill these distribution requirements will not include courses that fulfill other degree requirements, such as the Humanities and Arts Sufficiency 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 2211 Elements of Writing
   - EN 3215 Genres of Science Writing
   - EN 3216 Writing in the Professions
   - RH 3011 Electronic Documents or equivalent writing courses or ISPs

B. **Rhetoric and communication studies** (1 Unit)

   Recommended courses:
   - RH 3111 The Study of Writing
   - RH 3112 Rhetorical Theory ISP or any of the courses listed in Category I not used to fulfill that requirement.

C. **Electives** (1 unit)

   The 1 unit of electives must be coherently defined and approved by the student’s program review committee. Students may draw on:
   - Philosophy and ethics courses (such as PY 2711, PY 2713, PY 2714, PY 2716, PY 2717, PY/RE 2371, PY/RE 3731);
   - Foreign language courses;
   - Management courses.

### INTERNATIONAL STUDIES

**P.H. HANSEN, DIRECTOR**

**ASSOCIATED FACULTY:** W.A.B. Addison (HU), D.B. Dollemayer (HU), P.P. Dunn (HU), L. Fontanella (HU), P.H. Hansen (HU), M.J. Radzicki (SSPS), K.J. Rissmiller (SSPS), A. Rivera (HU), and J.F. Zeugner (HU)

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.

### MINOR IN INTERNATIONAL STUDIES

The goals of WPI’s minor in International Studies are to extend students’ global horizons, enhance their disciplinary majors, and expand their career opportunities in the international arena. The program develops a familiarity with global or international issues, an appreciation of cultural differences, and the ability to complete tasks abroad. The minor achieves a basic level of competence in International Studies through a variety of courses, projects, and overseas experiences.

The minor requires a minimum of three units of work related to International Studies as described below. After course work at WPI, students complete their minor through either an international IQP or an international exchange program approved by the Program Review.
Committee. All students are required to have an international experience off-campus. The program’s capstone experience is a Senior Seminar in International Studies. Both options receive the same designation of Minor in International Studies. A student in any major at WPI is eligible to pursue a Minor in International Studies.

Program Requirements for the International Studies Minor

INTERNATIONAL STUDIES IQP OPTION

<table>
<thead>
<tr>
<th>Requirement</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>

INTERNATIONAL STUDIES EXCHANGE PROGRAM OPTION

<table>
<thead>
<tr>
<th>Requirement</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 1315.
   b) A course in understanding cross-cultural differences, such as one of the following: HU 3411 Pro-Seminar in Global Perspectives, or SS 2406 Cross-Cultural Psychology; or SS 1202 Sociological Concepts and Comparative Analysis; or PY 2716 Philosophy of Difference.
   c) HU 4411 Senior Seminar in International Studies.

Courses in the core may not double-count towards other degree requirements such as the Humanities and Arts Sufficiency requirement or the two course requirement in the Social Sciences. If a student has already counted a course from a) or b) for another requirement, they will be required to take additional courses in International Studies so that at least one unit of their minor does not double-count. The capstone seminar should be the final element of a student’s minor.

2. International Electives may be selected from among international courses in the Humanities and Social Sciences. They may include any course in European or global history; any course at the intermediate level or above in German or Spanish; any international course in the social sciences; and international courses approved by the Program Review Committee in art history, literature, philosophy and religion. If approved by the Program Review Committee, PQPs for overseas projects may count towards the total. Students may count courses taken to fulfill other degree requirements towards these electives. These electives may not include the MQP or the final 1/3 unit Type 5 IS/P of the Sufficiency Program.

3. International IQP. Students who choose the IQP Option must complete an International IQP. All IQPs completed outside of the United States meet this requirement. If approved by the Program Review Committee, IQPs completed on-campus or at Project Centers in the United States may meet this requirement if the IQP is devoted to an international subject and the student also completes a study abroad experience as described in note 4.

4. International Experience: All International Studies minors are required to have a study abroad experience. Students who choose the Exchange Option must complete an international 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.

For general policy on the minor, see description on page 24.

MAJOR IN INTERNATIONAL STUDIES

The International Studies Major is an interdisciplinary program that combines rigorous preparation in international studies with competence in an area of science, technology, or management. Under the broad umbrella of the International Studies distribution requirements, students will be able to create their own flexible programs to accommodate their interests and career goals. MQPs may be completed on campus or at one of WPI’s global project centers. In consultation with the Program Review Committee, students plan a course of study that may focus on a region of the world, or a thematic issue, or an analytical approach to international studies. International Studies majors are well prepared for careers in business, government, and public affairs.

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>Electives (Note 4)</td>
<td>4</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 SS 2406 Cross-Cultural Psychology; or SS 1202 Sociological Concepts and Comparative Analysis; 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 Cultural History (e.g. AR 1111, AR 2111), English Literature (e.g. EN 2243, EN 3222), 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. SS 1320, SS 2105, SS 2125, SS 2312, SS 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. Electives may be from any area except Aerospace Studies, Military Science or Physical Education. Double-majors may count as electives courses taken for their other major. Majors who are not completing a double-major are required to complete a two-unit technical sufficiency in an area of science, engineering, or mathematics apart from these electives.

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.

RECOMMENDATIONS FOR STUDENTS

Students planning an International Studies minor, major, or double major should take their International Core courses in international history and cross-cultural differences before they go abroad. Since many students go off-campus during their Junior year, students should plan to take these Core courses in their Freshman and Sophomore years. Students are also encouraged to take their International Electives before going abroad and on topics that relate to their international experience. The capstone course, HU 4411, Senior Seminar in International Studies, should be the final element of the minor. Therefore, students may enroll in HU 4411 after they have completed all of the other requirements for the International Studies minor. Students planning an International Studies minor may also wish to consider the possibility of completing a double major in International Studies.

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 215.

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/.

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
   - SS 1310 Law, Courts and Politics
   - SS 2310 Constitutional Law
   - MG 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
   - SS 2311 Legal Regulation of the Environment
   - SS 2313 Intellectual Property Law
   - Independent study or experimental courses with the approval of the pre-law advisor

3. One of the following courses in professional communication:
   - EN 2211 Elements of Writing
   - EN 3216 Writing in the Professions
   - EN 3215 Genres of Science Writing
   - RH 3112 Rhetorical Theory

4. One of the following courses undertaken as a capstone experience:
   - SS 2304 Governmental Decision Making and Administrative Law
   - SS 2313 International Environmental Policy
If a student takes both SS 2304 and SS 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. SS 2304 and SS 2313 will be offered in C Term in alternate years. 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 44. Note: only one of the two units may be counted toward other college requirements.

For general policy on the Minor, see description on page 24.

MANAGEMENT

M. C. BANKS, HEAD
S. A. JOHNSON, DIRECTOR IE PROGRAM
PROFESSORS: M. C. Banks, A. Gerstenfeld, J. T. O’Connor, H. G. Vassallo
INSTRUCTORS: O. Volkoff
PROFESSOR OF PRACTICE: S. Kazin

INTRODUCTION

The Department of Management provides undergraduate and graduate management education designed to help aspiring managers and executives understand how to use technology to help organizations and individuals succeed in their business endeavors. Our courses combine a practical component, which helps our students apply what they learn, and a theoretical component, which helps them understand why it works and how to use it in other settings. Many courses include a strong global component to help our students understand business beyond the borders of the United States. That our approach is successful is demonstrated in our strong placement record, the above (national) average salaries of many of our graduates, and that within five years of graduation they earn, on average, more than any other WPI graduates in the same class.

We provide a number of educational opportunities for our students. We offer undergraduate majors in Industrial Engineering (IE), Management (MG), Management Engineering (MGE), and Management Information Systems (MIS), minors in Entrepreneurship, Management, Management Information Systems, and Organizational Leadership. At the graduate level we offer the MBA, MS in Operations and Information Technology, MS in Marketing and Technological Innovation, our combined BS/MBA program, and our graduate certificates in Technology Marketing, Management of Technology, Information Technology, and Electronic Commerce.

DEPARTMENT OF MANAGEMENT MISSION STATEMENT

The mission of the Department of Management at WPI is to provide its students with an integrated, technologically oriented education. Its project-based curriculum emphasizes both the theory and the practice of management and prepares students to assume positions of leadership in an increasingly global economic environment. Teaching and scholarship in the department encompass the disciplines of management and technology; emphasis is placed on the impact of technological change on both organizations and society in general. The Department stresses excellence in instruction and in applied research.

Please read on to learn more about our undergraduate programs.

INDUSTRIAL ENGINEERING

Industrial engineers focus on process improvement. The process might be a manufacturing line, where each process step is a physical operation that creates a product, or might involve paper and information, such as the steps required to apply to a particular college for admission. Improvement can mean reducing cost, reducing the time required to complete the process, or reducing the number of errors. To be effective, industrial engineers must combine technical knowledge with concerns about how people fit into the systems they design — skills that organizations need a lot right now. Industrial engineers take a systems view, considering all the resources (people, technology, information) that are part of the process. Industrial engineers find jobs in manufacturing firms, hospitals, transportation firms, and government agencies. An industrial engineer might be in charge of quality on a production line, develop computer models to improve service to patients in a hospital clinic, or work to reduce inventory costs. Many industrial engineers move into supervisory or management positions as their career progresses.

At WPI, the IE program is designed to provide students with the tools to spearhead process improvement efforts and the knowledge to implement and employ new technologies. Industrial engineering majors at WPI complete courses in three major categories: (1) the basic mathematics and science courses that are the foundation for all engineering disciplines, (2) core courses that address the tools that industrial engineers use to effect process improvements, including such things as computer simulation and theories of human behavior, and (3) elective courses that can be tailored to your career objectives.

The Major Qualifying Project (MQP) is an integral part of the education of our majors. In addition to satisfying a significant graduation requirement, the MQP must be focused on industrial engineering design. It is typically performed for a business organization. These two elements of our approach to MQPs result in a very valuable learning experience for all of our students. Examples of the MQP for industrial engineering majors include:

- Changeover Time Reduction: Enhancing Production Flexibility at Nypro Corporation
- Inventory Analysis of the Lightwave Business Unit at Lucent Technologies
- Supply Chain Analysis for the Medical Product Division at Hewlett Packard
- Simulation Study of Switcher Operations at an RPS Hub
OUR STRATEGIC INTENT
To be the premier provider of undergraduate and graduate education focused on the Management of Technology.

OUR MISSION
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.

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 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.
1. Mathematics must include differential and integral calculus.
2. 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 MG/IE courses and Operations Research courses in Mathematics qualify with the exception of courses in financial modeling and organizational science.
   c. 1 unit in technical electives. Industrial Engineering electives and any other Engineering Science/Design courses qualify.

**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 20), 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:

<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. Industrial Engineering Topics</td>
<td></td>
</tr>
<tr>
<td>(including the MQP) (Notes 3,4)</td>
<td>6</td>
</tr>
</tbody>
</table>

**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.

**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 ability to take the initiative.
   o. An understanding of change management in organizational settings.

**Curriculum Guidelines for IE**

Recommendations for complying with program distribution requirements (10 units) are described below. Students are encouraged to use a Program Tracking Sheet to plan their program and document their progress toward meeting degree requirements. Program tracking sheets are available on the IE web page or in the Management Department Office. To earn a Bachelor of Science (B.S.) degree in Industrial Engineering, students must complete 15 units of coursework. In addition to the requirements below, one must complete the Sufficiency requirement (2 units), the Interactive Qualifying Project (1 unit), free electives (1 unit), social sciences (2/3 unit), and physical education (1/3 unit). Students without prior programming experience are encouraged to take CS 1005 in their freshman or sophomore year.

1. **Mathematics and Basic Science (4 units)**
   Mathematics requirements include differential and integral calculus, ordinary differential equations, and 2/3 units probability and statistics. Mathematics requirements can be satisfied by taking MA 1021, MA 1022, MA 1023, MA 1024, MA 2051, MA 2611, and MA 2612. Other recommended courses include: MA 2071, courses in probability and statistics, and courses in numerical analysis.

   Basic science courses can be elected in chemistry, physics, biology, or geology. Students must take both chemistry and physics, with a minimum two-course sequence in one of these areas.

2. **Industrial Engineering Topics (5 units)**
   Students must choose 1 course in each of nine core areas, then choose one unit of industrial engineering and one unit of technical electives. Students who plan to take the Engineering Fundamentals examination in their senior year or to pursue a graduate degree in an engineering field should select their additional unit of work from the engineering science courses suggested under Technical Electives.
   **Industrial Engineering Core (3 units)**
   Choose one course from each area of the following nine areas:
   - Deterministic operations research methods: MG/IE 2500 - Management Science I or MA 4231 - Linear Programming
• process design: MG/IE 3400 - Production System Design or MG/IE 3405 - Work Systems and Facilities Planning
• production planning and control: MG/IE 3401 - Production Planning and Control
• simulation: MG/IE 3460 - Simulation Modeling and Analysis or CS 4231 - Simulation Modeling and Analysis
• stochastic methods: MG/IE 3420 - Quality Planning, Design, and Control or MG/IE 3501 - Management Science II
• information systems design: MG 2720 - Business Application Development Tools or MG 2710 - Business Application Platforms
• financial modeling: MG/IE 2200 - Financial Management or MG/IE 2850 - Engineering Economics
• organizational science: MG/IE 2300 - Organizational Science Foundation or MG/IE 3351 - Org. Sci. Management of Change
• engineering basics outside IE: see comments below

The engineering basics course is designed to allow students to explore some of the fundamental engineering knowledge associated with either manufacturing or service systems. Depending on the systems that are most interesting to them, it is recommended that students select one course from the following lists:


**Industrial Engineering Electives (1 unit)**

To achieve depth in their IE program, students are required to take one additional unit of advanced IE courses. Students may choose to focus in operations design and planning, information systems design, or operations research, or to elect a more general program by selecting courses from several areas. A course counted toward the IE core cannot be counted again as an elective. Industrial Engineering courses (listed with an MG/IE designation) and Operations Research courses in Mathematics at the 3000/4000 level qualify with the exception of courses in financial modeling and organizational science.

**Technical Electives (1 unit)**

Industrial Engineering electives and other Engineering Science/Design courses qualify. Courses that can be counted as Engineering Science/Design are described on page 32.

For students planning on taking the Fundamentals of Engineering examination, the following courses are recommended:

EE 3601 - Principles of Electrical Engineering
ES 2001 - Introduction to Materials Science
ES 2501 - Introduction to Static Systems
ES 2503 - Introduction to Dynamic Systems
ES 3000 - Classical Thermodynamics
ES 3004 - Fluid Mechanics

(3) **Major Qualifying Project (1 unit)**

The MQP is expected to provide a capstone design experience for industrial engineering majors. If the MQP does not fulfill this 1/3 unit requirement, the student should speak with the Industrial Engineering Program Director to determine an appropriate method for fulfilling this requirement.

**MANAGEMENT (MG)**

The Management major at WPI is what many colleges and universities call “General Business.” Our approach is to provide a broad understanding of business through what we refer to as Foundation Courses. These include such courses as Financial and Managerial Accounting, Marketing Management, and Operations Management. On top of the Foundation Courses, each student selects six courses as the focus of their advanced work. These courses should be selected from the MG list found in the section, Curriculum Guidelines For MG, MGE, MIS. Courses not on this list must be approved by your academic advisor and the Department’s Undergraduate Policy & Curriculum Committee (UPCC). This latter option permits you to develop a plan of study that is tailored to your career objectives. Career opportunities for management students can be found in banking and finance, manufacturing management, marketing and sales, research and development, human resources, public or not-for-profit sector management, and many other occupations.

The Major Qualifying Project (MQP) is an integral part of the education of our MG majors. In addition to satisfying a significant graduation requirement, the MQP must be focused in the student’s specific focus area. It is typically performed for a business organization. These two elements of our approach to MQP’s result in a very valuable learning experience for all of our students. Examples of the MQP for Management majors include:

- establishing an activity-based costing system in a manufacturing facility,
- developing a total quality management program for increasing productivity in a service organization,
- developing a global sourcing program for a manufacturing firm, and
- identifying and developing a solution for a manufacturing quality problem.

**Objectives of the Management Major are:**

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

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.
## Sample Student Program with Overseas IQP and an Internship

<table>
<thead>
<tr>
<th>FIRST YEAR</th>
<th>SECOND YEAR</th>
<th>THIRD YEAR</th>
<th>FOURTH YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sufficiency 1</td>
<td>Sufficiency 5</td>
<td>IQP (overseas project center)</td>
<td>Major Course 4</td>
</tr>
<tr>
<td>Sufficiency 2</td>
<td>Sufficiency 6</td>
<td>MG 3400</td>
<td>Major Course 5</td>
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<tr>
<td>Sufficiency 3</td>
<td>MG 2101</td>
<td>MG 3600</td>
<td>Major Course 6</td>
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<tr>
<td>Sufficiency 4</td>
<td>MG 2300</td>
<td>MG 3700</td>
<td>MQP</td>
</tr>
<tr>
<td>MA 1021</td>
<td>MG 2500</td>
<td>Major Course 1</td>
<td>Free Elective</td>
</tr>
<tr>
<td>MA 1022</td>
<td>MG 2950</td>
<td>Major Course 2</td>
<td>Free Elective</td>
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<tr>
<td>MA 2611</td>
<td>CS 1005</td>
<td>Major Course 3</td>
<td>Free Elective</td>
</tr>
<tr>
<td>MA 2612</td>
<td>Science 1</td>
<td>MG Elective (3000 or 4000)</td>
<td>Free Elective</td>
</tr>
<tr>
<td>SS 1110</td>
<td>Science 2</td>
<td>MG Elective</td>
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<tr>
<td>SS 1120</td>
<td>PE 1</td>
<td></td>
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</tr>
<tr>
<td>MG 1100 (C term)</td>
<td>PE 2</td>
<td></td>
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</tr>
<tr>
<td>MG 2200 (D term)</td>
<td>Internship</td>
<td></td>
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</table>

## Sample Student Program with No Off Campus Components

<table>
<thead>
<tr>
<th>FIRST YEAR</th>
<th>SECOND YEAR</th>
<th>THIRD YEAR</th>
<th>FOURTH YEAR</th>
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<tbody>
<tr>
<td>Sufficiency 1</td>
<td>Sufficiency 5</td>
<td>IQP 1</td>
<td>Major Course 4</td>
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<tr>
<td>Sufficiency 2</td>
<td>Sufficiency 6</td>
<td>IQP 2</td>
<td>Major Course 5</td>
</tr>
<tr>
<td>Sufficiency 3</td>
<td>MG 2101</td>
<td>IQP 3</td>
<td>Major Course 6</td>
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<tr>
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<td>MQP</td>
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<tr>
<td>MA 1021</td>
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<tr>
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<td>Major Course 2</td>
<td>Free Elective</td>
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<tr>
<td>SS 1110</td>
<td>Science 2</td>
<td>Major Course 3</td>
<td>Free Elective</td>
</tr>
<tr>
<td>SS 1120</td>
<td>Free Elective</td>
<td>MG Elective (3000 or 4000)</td>
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<tr>
<td>MG 1100 (C term)</td>
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<td>MG Elective</td>
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<td>MG 2200 (D term)</td>
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<tr>
<td>PE 1</td>
<td>PE 3</td>
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<tr>
<td>PE 2</td>
<td>PE 4</td>
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## Sample Student Program Including Summer and Co-op

<table>
<thead>
<tr>
<th>FIRST YEAR</th>
<th>SECOND YEAR</th>
<th>THIRD YEAR</th>
<th>FOURTH YEAR</th>
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</thead>
<tbody>
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<td>Sufficiency 1</td>
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<td>IQP 1</td>
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<td>Sufficiency 2</td>
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<td>IQP 2</td>
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<td>Sufficiency 3</td>
<td>MG 2101</td>
<td>IQP 3</td>
<td>Major Course 6</td>
</tr>
<tr>
<td>Sufficiency 4</td>
<td>MG 2300</td>
<td>MG 3400</td>
<td>MQP</td>
</tr>
<tr>
<td>MA 1021</td>
<td>MG 2500</td>
<td>MG 3600</td>
<td>Free Elective</td>
</tr>
<tr>
<td>MA 1022</td>
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<td>MG 3700</td>
<td>MG Elective</td>
</tr>
<tr>
<td>MA 2611</td>
<td>CS 1005</td>
<td>Major Course 1</td>
<td></td>
</tr>
<tr>
<td>MA 2612</td>
<td>Science 1</td>
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<td>Cooperative Education Experience</td>
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</tr>
<tr>
<td>MG 1100 (C term)</td>
<td>Free Elective</td>
<td>(D- and E-Terms)</td>
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</tr>
<tr>
<td>MG 2200 (D term)</td>
<td>Free Elective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE 1</td>
<td>Free Elective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE 2</td>
<td>Free Elective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**First Summer**

3 Free Electives
MANAGEMENT ENGINEERING (MGE)

Management Engineering at WPI combines the best of a business degree with a technical focus. MGE majors develop a broad understanding of business through what we refer to as Foundation Courses. These include such courses as Financial and Managerial Accounting, Marketing Management, and Operations Management. On top of the Foundation Courses, each student selects six courses as the focus of their advanced work. These courses should be selected from the MGE list found in the section, Curriculum Guidelines For MG, MGE, MIS. Courses not on this list must be approved by your academic advisor and the Department’s Undergraduate Policy & Curriculum Committee (UPCC) and usually come from electives in the Department or from areas such as Engineering, Mathematics, or Science. Career opportunities for Management Engineering majors are quite varied. While many become engineers in the focus area (Industrial Engineering, for example), many join management training programs or accept sales positions with technological firms.

The Major Qualifying Project (MQP) is an integral part of the education of our MGE majors. In addition to satisfying a significant graduation requirement, the MQP must be focused in the student’s specific focus area. It is typically performed for a business organization. These two elements of our approach to MQPs result in a very valuable learning experience for all of our students. Examples of the MQP for Management Engineering majors include:

- economic justification of robotic systems for automatic inspection,
- productivity analysis in a job-shop environment, and implementation and analysis of total quality management programs.

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.

MANAGEMENT INFORMATION SYSTEMS (MIS)

Like our other major programs in the Department of Management, the Management Information Systems program combines a broad understanding of business, through what we refer to as Foundation Courses, with specialized education in Information Systems. Foundation Courses include such areas as Financial and Managerial Accounting, Marketing Management, and Operations Management. On top of the Foundation Courses, each student selects six MIS courses as the focus of their advanced work. These courses should be selected from the MIS list found in the section, Curriculum Guidelines For MG, MGE, MIS. Courses not on this list must be approved by your academic advisor and the Department’s Undergraduate Policy & Curriculum Committee (UPCC) and usually come from electives in the Department or from areas such as Computer Science or Electrical & Computer Engineering.

Based on the rigorous IS ’97 Guidelines for MIS programs, our MIS courses cover such areas as business application platforms, business application development tools, data management, and telecommunications, among others. This program helps students develop strong analytical, problem solving, and communication skills, and a solid understanding of business and computing. Many of our MIS majors join international consulting firms upon graduation, while others take entry-level positions as programmer-analysts, business analysts, end-user support staff, and eventual management training positions in high-technology businesses.

The Major Qualifying Project (MQP) is an integral part of the education of our MIS majors. In addition to satisfying a significant graduation requirement, the MQP must be focused in the student’s specific focus area. It is typically performed for a business organization. These two elements of our approach to MQPs result in a very valuable learning experience for all of our students. Typical MQPs for MIS majors include:

• B2B E-commerce applications,
• B2C E-commerce applications,
• design and development of organizational database systems, and
• decision support systems.

Clients have included both small and large companies as well as manufacturing businesses, consulting firms, public sector organizations, and university departments.

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 platforms;
• 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 Management Degrees (MG, MGE, and MIS)

<table>
<thead>
<tr>
<th>Requirements (MG, MGE, MIS)</th>
<th>Minimum Units</th>
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</thead>
<tbody>
<tr>
<td>1. Management Foundation (Note 1)</td>
<td>11/3</td>
</tr>
<tr>
<td>2. Mathematics (Note 2)</td>
<td>4/3</td>
</tr>
<tr>
<td>3. Basic Science</td>
<td>2/3</td>
</tr>
<tr>
<td>4. Management Major (Note 3)</td>
<td>6/3</td>
</tr>
<tr>
<td>5. Management Electives (Note 4)</td>
<td>3/3</td>
</tr>
<tr>
<td>6. Computer Science</td>
<td>1/3</td>
</tr>
<tr>
<td>7. MQP</td>
<td>3/3</td>
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<tr>
<td>(Note 5)</td>
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<tr>
<td>Total</td>
<td>10</td>
</tr>
</tbody>
</table>

NOTES:
1. 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, microeconomics, macroeconomics, and business law and ethics.
2. Mathematics must include 2/3 units of calculus and 2/3 units of statistics.
3. The Management Majors (other than IE) must comprise a department-approved integrated set of courses covering a specific area of: management, science, engineering or mathematics for MGE; computer science or information systems for MIS; management, social sciences, or humanities for MG.
4. Management electives must include at least 1/3 unit of 3000/4000 level MG courses. The remaining 2/3 units specified in the requirement may be satisfied with courses from Mathematics, Basic Science, Computer Science, Management, or Social Science, but excluding courses MG 1250, and MG/IE 2850.
5. Courses may not be counted more than once in meeting the departmental distribution requirements. The total number of MG (and/or MG/IE) units may not exceed 50% of the total number of units earned for the degree.

Curriculum Guidelines for MG, MGE, MIS

Specific course recommendations for complying with the distribution requirements are given below. These guidelines are intended to offer flexibility while meeting minimal standards in preparing for careers in MG, MGE, or MIS.

Mathematics—minimum of 4/3 units is required, with 2/3 units in calculus and 2/3 units in statistics. For most students, MA 1021, MA 1022, MA 2611, and MA 2612 will be appropriate.

Basic Science—minimum of 2/3 unit is required, where all courses with the prefix PS, CH, and BB, as well as GE 2341 and GE 3050, qualify.

Computer Science—minimum of 1/3 unit is required, where all courses with the prefix CS qualify (except CS 3043). Either CS 1005 or CS1006 is recommended.

Management—minimum of 4 units is required with 2/3 units in accounting and 2/3 units in economics, and 1/3 unit from each of the 8 remaining management categories designated below. Recommended courses are listed. These courses represent the basic courses in each functional area of Management. It is recommended that courses SS 1100, SS 1120, MG 1100, and MG 2200 be taken during the first year.

Management Foundation Coursework

Accounting
MG 1100 and MG 2101
Economics
SS 1110 and SS 1120
Finance
MG/IE 2200
Organizational Science
MG/IE 2300
Quantitative Methods
MG/IE 2500
Business Law & Ethics
MG 2950
Production
MG/IE 3400
Marketing
MG 3600
Information Systems
MG 3700
3000- or 4000-level MG elective

Major—minimum of 2 units of integrated core work is required for students majoring in Management, MIS, or Management Engineering. Other courses may be used but must be approved by the student’s academic advisor and the Department’s Undergraduate Policy & Curriculum Committee early in the student’s program.

MG
Complete six (6) of the following: MG1900, MG2250, MG2260, MG2720, MG/IE351, MG/IE3400 OR MG/IE3401, MG3640, MG3651, MG3720, MG3910, MG3920, MG4151, MG4364, MG4365, MG4930. Students wishing to use other courses as part of the Management major should secure the approval of their MG academic advisor and the Department of Management’s Undergraduate Policy & Curriculum Committee (UPCC).

MGE
Complete six (6) of the following: MG2720, MG/IE3351, MG/IE3400 OR MG/IE3401, MG/IE3420, MG/IE3501, MG3651, MG3640, MG3720, MG4151, MG4364, MG4365, MG/IE 4410. Students wishing to use other courses as part of the MGE major should secure the approval of their MGE academic advisor and the Department of Management’s Undergraduate Policy & Curriculum Committee (UPCC).

MIS
Management Information Systems
CS2005, MG2710, MG2720, MG/IE3720, MG/IE4720, and one of the following: MG/IE3740, MG4750, CS2011, CS3013, CS3041, CS4514. Students wishing to use other courses as part of the MIS major should secure the approval of their MIS academic advisor and the Department of Management’s Undergraduate Policy & Curriculum Committee (UPCC).
BREADTH-In addition to the guidelines listed above for Mathematics, Basic Science, Computer Science, and Management, the departmental distribution requirements call for an additional 2/3 units, which may be distributed across these categories as well as social science.

MANAGEMENT NONMAJOR INFORMATION
Often the courses of the Department will be used as a small portion of other degree programs. Since management background is increasingly important, the nonmajor function is selected by many students. Areas for either exposure or focus for the non-management major include marketing, accounting, finance, entrepreneurship, operations, and organization science. Special topics or projects can be arranged on a limited basis. Care should be taken that MG and MG/IE courses do not exceed 25 percent of the total units taken for a degree.

FIVE-YEAR DUAL DEGREE BS/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 B.S. 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 Combined B.S./MBA Program. A separate and complete application to the MBA program must be submitted. Admission to the Combined Program is determined by the faculty of the Department of Management. The student should begin the curriculum planning process at the time he/she commences his/her undergraduate studies to ensure that all of the required prerequisite undergraduate courses are completed within the student's four years of undergraduate study. It is recommended that the MBA application be submitted at the beginning of the student's Third Year of undergraduate study. A student in the Combined Program continues to be registered as an undergraduate until the bachelor's degree is awarded.

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

- MG 1100  Financial Accounting
- MG/IE 2200  Financial Management
- MG/IE 2300  Organizational Science
- MA2611  Applied Statistics I
- MA2612  Applied Statistics II
- MG/IE 3400  Production System Design
- MG 3600  Marketing Management
- MG 3700  Information Systems Management
- SS 1110  Introductory Microeconomics
- SS 1120  Introductory Macroeconomics

To obtain an MBA via the Combined 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:

- MG511  Interpersonal and Leadership Skills for Technological Managers
- MG512  Creating and Implementing Strategy for Technological Organizations
- MG513  Creating Processes in Technological Organizations
- MG514  Business Analysis for Technological Managers
- MG515  Legal and Ethical Context of Technological Organizations
- MG516  Graduate Qualifying Project (GQP)

12 Elective Credits

A student in the Combined 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 Combined 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. Students in the Combined Program may use advanced undergraduate major or elective courses (generally classified as 4000-level courses) to satisfy graduate degree elective requirements. The Department of Management decides which courses may be used in this way. Faculty members teaching these advanced undergraduate courses may impose special requirements, appropriate to an undergraduate course being used for graduate credit, on Combined Program students.

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 Combined Program.

The Combined Program is a full-time program of study. Once admitted to the Combined Program, a student must register every fall and spring semester until the MBA is completed. A student in the Combined Program who has no registered activities during a given fall or spring semester is automatically terminated from the Combined Program, and may only be readmitted to the Combined 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 Combined Program does not affect a student's ability to continue toward the bachelor's degree.

COURSE AREAS AND NUMBERING
The second digit of undergraduate Management course numbers denotes the subject area as follows:

0 - General
1 - Accounting
2 - Finance
3 - Organizational Science
4 - Operations Management and Industrial Engineering
5 - Management Science
6 - Marketing
7 - Management Information Systems
8 - Managerial Economics
9 - Entrepreneurship and Special Topics
ENTREPRENEURSHIP MINOR

All around the world people are starting their own new business ventures. With its strong heritage of entrepreneurship, 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 MQP that they will then turn into a business upon graduation. Related opportunities include a business plan competition, a virtual incubator for E-commerce businesses, the WPI chapter of CEO (Collegiate Entrepreneurs Organization), 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 free electives.

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

1. Complete the following course:
   MG/IE2850 Engineering Economics

2. Complete two (2) from the following list:
   MG1100 Financial Accounting OR
   MG2101 Management Accounting
   MG2950 Business Law & Ethics
   MG3400 Production System Design
   MG3600 Marketing Management
   MG3700 Information Systems Management

3. Complete the following three courses, preferably in order:
   MG3910 Identifying & Evaluating New Venture Opportunities
   MG3920 Planning & Launching New Ventures
   MG4930 Growing and Managing 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 24.

MANAGEMENT MINOR

Everyone needs management skills. If engineers, scientists, and other 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 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 group of courses:
   MG1900: Introduction to Business in an International Environment OR MG/IE 2300 Organizational Science

2. **Three courses** from the group of courses:
   a. MG1900 Introduction to Business in an International Environment OR MG/IE 2300 Organizational Science
   AND
   b. MG1100 Financial Accounting OR MG2101 Management Accounting
   AND
   c. One 2000-level course with prefix MG or MG/IE

3. One 3000 or 4000-level course with prefix MG or MG/IE

4. Capstone Experience MG4930:

**NOTE:**
The courses selected for the minor must include not more than one course from any Management Subject Area. The Areas are reflected in the second digit of any MG course number.

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 24.

MANAGEMENT INFORMATION SYSTEMS MINOR

Information technology has been the driving force behind the current economic boom in the U.S. It is 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 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:
   MG1900: Introduction to Business in an International Environment OR
   MG1100: Financial Accounting OR
   MG2101: Management Accounting OR
   MG/IE2300: Organizational Science

2. **Two CS courses, or their equivalents, from the following courses:**
   CS1005: Introduction to Programming in C
   CS1006: Introduction to Programming in Java
   CS2005: Techniques of Programming

3. **Two courses** from the group of courses:
   MG 3700: Information Systems Management
   MG/IE3720: Management of Data
   MG/IE3740: Organizational Application of Telecommunications
4. Capstone Experience
MG/IE 4720: Systems Analysis and Design
Course MG/IE 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 of the Minor, see the description on page 24.

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 be 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:
MG 1900 Introduction to Business in an International Environment
MG/IE 2300 Organizational Science - Foundation
MG 2950 Business Law & Ethics
MG/IE 3351 Organizational Science - Management of Change
MG 4364 Human Resource Management

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

3. Required Capstone Experience
MG 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 free electives, as appropriate.
For general policy on the Minor, see the description on page 24.

MANUFACTURING ENGINEERING

DIRECTOR: C. A. Brown
PROFESSORS: D. Apelian, R. D. Sisson
PROFESSOR OF PRACTICE: S. Mirza
ASSISTANT PROFESSOR: M. Fofana
LECTURER: P. D. Cotnoir

INTRODUCTION
The Manufacturing Engineering program is multidisciplinary in nature, and relies on faculty and equipment primarily of the departments of Computer Science, Electrical and Computer Engineering, Management, and Mechanical Engineering.
Manufacturing Engineering integrates basic knowledge of materials, design, processes, computers, engineering analysis, and systems design. This knowledge is used to design, build, operate, and manage production systems. Manufacturing Engineering encompasses a wide range of areas from basic research to technical management. At WPI, Manufacturing Engineers may be involved through courses and MQPs in a wide range of topics including:
- Clean Manufacturing and Environmental Issues
- Computer-Aided Design (CAD)
- Computer-Aided Manufacturing (CAM)
- Manufacturing Processes (Casting, Welding, Machining, Forming, Injection Molding, etc.)
- Factory Automation
- Design for Assembly
- Design for Manufacturing
- Design for the Environment
- Industrial Robotics
- Processing of Metals, Ceramics, Plastics, and Composite Materials
- Powder Ceramics and Metals Processing
- Design with Advanced Materials
- Manufacturing Automation Protocol (MAP)
- Just-in-Time Manufacturing (JIT)
- Computer Integrated Manufacturing (CIM)
- Group Technology
- Process Planning and Control
- Flexible Manufacturing Systems (FMS)
- Manufacturing of Prosthetic and Orthotic Biomedical Devices
- Process Simulation and Analytical Modeling
- Factory of the Future
- Simultaneous/Concurrent Engineering.

The MFE program emphasizes a “systems” oriented approach in which topics are discussed not only as separate entities but also as integral elements of a unified program. All aspects are considered: product design, analysis, manufacturing, and testing — usually in an automated factory environment.
A scientific “high technology” basis for manufacturing engineering is evolving. The MFE program is designed to place WPI students at the leading edge of this evolution.
**MANUFACTURING ENGINEERING PROGRAM CHART**

### BACKGROUND

<table>
<thead>
<tr>
<th>4 Units</th>
<th>2/3 Units</th>
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<tbody>
<tr>
<td><strong>MATHEMATICS</strong></td>
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<tr>
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<td>BB 1020</td>
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<tr>
<td>MA 3613</td>
<td></td>
</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.

### 1/3 Unit

**PHYSICAL EDUCATION**

see page 135

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

**One unit per area required**

**Electives**

<table>
<thead>
<tr>
<th>1 Unit</th>
<th>1 Unit</th>
<th>1 Unit</th>
<th>1 Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MATERIALS &amp; PROCESSES</strong></td>
<td><strong>PRODUCT ENGINEERING</strong></td>
<td><strong>COMPUTER CONTROL &amp; MANUFACTURING SYSTEMS</strong></td>
<td><strong>PRODUCTION SYSTEMS ENGINEERING</strong></td>
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<tr>
<td>ES 2001</td>
<td>ES 2501</td>
<td>EE 3601</td>
<td>MG/IE 2850</td>
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<td>ME 1800</td>
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<td>ME/BE 4814</td>
<td>ME 3311</td>
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<td>ME 4320</td>
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</table>

1 Unit Emphasizing Design

**MAJOR QUALIFYING PROJECT (MQP)**

**FREE ELECTIVE**

Refer to catalog

**INTERACTIVE QUALIFYING PROJECT (IQP)**

see page 37

**H&A SUFFICIENCY**

see page 51

**SOCIAL SCIENCE**

see page 142
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 (see page 20), students wishing to receive the degree designated “Manufacturing Engineering” must satisfy certain distribution 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.

PLANNING A PROGRAM IN MANUFACTURING ENGINEERING

The MFE program is constructed in a manner similar to other engineering programs. Background and competence is developed in mathematics and the basic sciences. Other WPI requirements, including the Humanities and Arts Sufficiency, social science, and IQP, must be completed. Expertise in the four areas of Manufacturing Engineering is developed. Finally, the MQP, a capstone engineering design project that integrates previous WPI education, is completed.

The chart on page 117 is intended to assist in student planning. The units listed indicate minimum units required. Although the courses listed are appropriate for most students, it is possible to develop programs using other WPI courses. Since the MFE program is multidisciplinary in nature and has a wide range of electives, student programs should be developed in consultation with their academic advisor and the Director of Manufacturing Engineering.

FIVE-YEAR DUAL-DEGREE BS/MS PROGRAM

Outstanding undergraduate students in the B.S. program in Manufacturing Engineering and the other engineering and science programs at WPI are encouraged to apply for the five-year BS/MS program in Manufacturing Engineering. This dual-degree program can be completed in five years; however, the program is demanding and curriculum planning with the student’s academic advisor and the Director of Manufacturing Engineering should start during the third year at WPI in order to meet both degree requirements. (See page 225, and contact the Director of Manufacturing Engineering for details.)

MATERIALS ENGINEERING

Courses and programs of study in materials engineering are included in the Mechanical Engineering Department (page 126). 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
   - CM 3601 Chemical Materials Engineering
   - EE 3901 Semiconductor Devices
   - ME 2820 Materials Processing
   - ME 3023 Mechanical Behavior and Modeling Properties of Engineering Materials
   - ME 3811 Microstructure Analysis and Control
   - ME 3825 Mechanical Metallurgy Laboratory
   - ME 4813 Ceramics
   - ME/BE 4814 Biomaterials
   - ME 4816 Materials Optimization for Engineers
   - ME 4821 Chemistry, Properties, and Processing of Plastics
   - ME 4822 Solidification Processes
   - ME 4832 Corrosion and Corrosion Control
   - ME 4840 Physical Metallurgy
   - ME 4850 Solid State Thermodynamics
   - 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; CM 508, Catalysis and Surface Science of Materials; CM 510, Particle Systems; CM 543, Molecular Sieves; CM 551, Structure and Properties of Polymeric Materials; CH 555, Advanced Topics/Polymer Chemistry and Advanced Topics/Nanotechnology.
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 4816 and ME 4822. 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 24 of the Undergraduate Catalog.)
b. Undergraduates in any major who are considering graduate study in Materials Science and Engineering are advised to include ME 3023, ME 3811, ME 4840, and ME 4850 among their electives.
c. 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.
d. 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.
e. 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, CM, 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.
f. 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), Karen McNamara (CM).

PERMISSIBLE MAJOR-MINOR COMBINATIONS
The Materials Minor is available to students of all majors. Students can earn either a Materials Minor designation or a Materials Concentration, not both.
ground on which MQP topics are developed. Many MQPs involve the solution of real-world problems proposed by industrial sponsors. Details can be found at http://www.wpi.edu/~cims.

Students should choose an MQP area as early as possible so that an appropriate program of study may be designed. This is especially important for students who choose an MQP area that is different from computational analysis, discrete mathematics, operations research, or probability-statistics. In these cases, the students should plan their programs carefully with their advisors so that sufficient backgrounds are obtained by the time the students begin their MQPs.

Brief descriptions of the general distribution requirements as well as project opportunities and courses of interest are given below.

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:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
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<tbody>
<tr>
<td>1. Mathematics including MQP (See notes).</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).</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 3613.

Project Opportunities in Mathematical Sciences

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 include 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 for Engineers
- 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 4255 Numerical Analysis II
- MA 4291 Applicable Complex Variables
- MA 4411 Numerical Analysis of Differential Equations
- MA 4451 Boundary Value Problems
- MA 4473 Partial Differential Equations

DISCRETE MATHEMATICS

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
MA 2271 Graph Theory
MA 2273 Combinatorics
MA 3231 Linear Programming
MA 3233 Discrete Optimization
MA 4891 Topics in Mathematics (when appropriate)
CS 2005 Data Structures and Programming Techniques
CS 4120 Analysis of Algorithms
CS 4123 Theory of Computation

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 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-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
MA 4632 Probability and Mathematical Statistics II
MG 2500 Management Science I: Deterministic Decision Models
MG 3501 Management Science II: Risk Analysis
MG 3760 Simulation Modeling and Analysis

PROBABILITY-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 making such decisions. Probabilists and statisticians are also deeply involved in stochastic modeling - the development and application of mathematical models of random phenomena.

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 B.S. degree. More information about careers in statistics can be found at the American Statistical Association's web site http://www.amstat.org/profession/index.html.

Students planning on graduate studies in this area would be well advised to take, in addition to the courses of interest listed below, additional independent study or PQP work in probability-statistics.

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
MA 4632 Probability and Mathematical Statistics II

PROGRAM IN ACTUARIAL MATHEMATICS
An actuary is a business professional who uses mathematical skills to define, analyze, and solve financial and social problems. Preparation for a career as an actuary requires mathematical aptitude, but actuarial work involves a practical type of mathematical ability mixed with business skills. An actuary deals with real-life problems rather than theoretical ones, must be curious, have sound judgment, and be able to think logically and creatively. The goal of the program in actuarial mathematics is to prepare students for positions in life and health insurance companies, property and casualty insurance companies, consulting firms, or state or federal government agencies.

The most widely accepted standard of professional qualification to practice as an actuary in the United States is a Fellowship in either the Society of Actuaries (SoA) or the Casualty Actuarial Society (CAS). Each organization administers a series of examinations leading to Fellowship. The first few in this series are mathematical in nature covering topics in calculus and linear algebra, probability, mathematical and applied statistics. Students interested in the actuarial mathematics program should read the latest SoA Associateship Catalog for more information. This catalog may be obtained from the Department of Mathematical Sciences, or at http://www.soa.org.

The actuarial mathematics program at WPI provides the first steps in preparing for these examinations and an introduction to fundamentals in business and economics. Students with mathematical aptitude should be able to pass the first two SoA examinations before graduation.

After graduation, most actuarial training is through self-study combined with on-the-job experience. Many employers rotate their actuarial trainees through various assignments exposing them to different aspects of business operations. In addition, companies frequently maintain actuarial libraries, sponsor group study sessions, and give trainees study time during work hours.

Brief descriptions of the distribution requirements, project opportunities and the actuarial examinations are given below.
## MATHEMATICAL SCIENCES PROGRAM CHART

<table>
<thead>
<tr>
<th>2 UNITS H&amp;A SUFFICIENCY</th>
<th>see page 51</th>
</tr>
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<tbody>
<tr>
<td>1 UNIT INTERACTIVE QUALIFYING PROJECT</td>
<td>see page 37</td>
</tr>
<tr>
<td>2/3 UNIT SOCIAL SCIENCE</td>
<td>see page 142</td>
</tr>
<tr>
<td>1/2 UNIT PHYSICAL EDUCATION</td>
<td>see page 135</td>
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<table>
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<th>TRANSITION COURSES</th>
<th>CORE COURSES</th>
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### OTHER MA COURSES TO ATTAIN TOTAL OF 6 UNITS:

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<th>ALGEBRA</th>
<th>DISCRETE MATH</th>
<th>COMPUTATIONAL MATH</th>
<th>OPERATIONS RESEARCH</th>
<th>STATISTICS/PROBABILITY</th>
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</table>

### 1 UNIT MAJOR QUALIFYING PROJECT (MQP)

### 2/3 UNITS COMPUTER SCIENCE COURSES | see page 90

* Category II courses, offered in alternating years.
ACTUARIAL MATHEMATICS FLOW CHART

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<th>INTRODUCTORY COURSES</th>
<th>TRANSITION COURSES</th>
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OTHER MA COURSES TO ATTAIN A TOTAL OF 6 UNITS:

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<th>ACTUARIAL MATH</th>
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<th>ALGEBRA</th>
<th>DISCRETE MATH</th>
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<th>STATISTICS/PROBABILITY</th>
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</tr>
<tr>
<td>MA 4214*</td>
<td>MA 4291</td>
<td>MA 3825*</td>
<td>MA 3233*</td>
<td></td>
<td>MA 4237*</td>
<td>MA 3627*</td>
</tr>
<tr>
<td></td>
<td>MA 4451</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MA 3631</td>
</tr>
<tr>
<td></td>
<td>MA 4473*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MA 4214*</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>MA 4631</td>
</tr>
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<td></td>
<td>MA 4632</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MA 4658</td>
</tr>
</tbody>
</table>

1 UNIT MAJOR QUALIFYING PROJECT (MQP)

2/3 UNIT COMPUTER SCIENCE COURSES

4/3 UNITS MANAGEMENT COURSES

* Category II courses, offered in alternating years.
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:

<table>
<thead>
<tr>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics (including MQP) (See notes 1-6).</td>
</tr>
<tr>
<td>Management (See note 7).</td>
</tr>
<tr>
<td>Additional courses or independent studies (except MS, PE courses, and other degree requirements) from any area (See note 8).</td>
</tr>
</tbody>
</table>

NOTES:
1. Must include MA 3255, MA 3831, and MA 3832 or their equivalents.
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 3613.
7. Must include MG 2101 and MG 2200 or their equivalents.
8. Must include 2/3 units of computer science.

Project Opportunities in Actuarial Sciences

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. 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.

WPI COURSES AND THE SOCIETY OF ACTUARIES (SOA) EXAMINATIONS

JOINTLY SPONSORED EXAMS
The formulation of the distribution requirements for the program in actuarial mathematics was in large part motivated by the nature of the sequence of examinations that lead to Fellowship in the SoA or CAS. In particular, there are a number of WPI courses that cover fundamental topics that are included on the first few exams in this sequence.

<table>
<thead>
<tr>
<th>Society of Actuaries Examination</th>
<th>WPI Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematical Foundations of Actuarial Science</td>
<td>MA 1021 to MA 1024, MA 2631</td>
</tr>
<tr>
<td>2. Interest Theory, Economics and Finance</td>
<td>MA 3211, SS 1110, SS 1120, MG 1100, MG 2200</td>
</tr>
<tr>
<td>3. Actuarial Models</td>
<td>MA 3212, MA 4213, MA 4214, MA 2431, MA 4237</td>
</tr>
<tr>
<td>4. Actuarial Modeling</td>
<td>In addition to topics in 3: MA 2071, MA 2611, MA 2612, MA 3627.</td>
</tr>
</tbody>
</table>

It must be emphasized that course work alone is not sufficient preparation for the examinations listed above; passage requires additional self-study. Several publications of the Society of Actuaries are available in the mathematics department office, and comprehensive information may be found at http://www.soa.org and http://www.casact.org. In addition, requests for information about the actuarial profession can be sent to the Society of Actuaries, 475 North Martingale Road, Suite 800, Schaumburg, IL 60173-2226.

PROJECTS/INDEPENDENT STUDIES

Many MQP and independent study possibilities are available to students in the mathematical sciences. From among these, students should select MQP and independent study topics which are related to their areas of concentration. Some project and independent study areas are given below. In addition, a current listing of specific available projects with their descriptions is available at the department office, and at http://www.wpi.edu/Academics/Projects/available.html.

<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Faculty Advisor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuarial Mathematics</td>
<td>A. Heinricher, A. Wiedie</td>
</tr>
<tr>
<td>Advanced Differential Equations</td>
<td>P. W. Davis, W. Farr</td>
</tr>
<tr>
<td>Applications of Graph Theory</td>
<td>P. R. Christopher, W. J. Martin</td>
</tr>
<tr>
<td>Applied Mathematics and Mathematical Physics</td>
<td>J. D. Fehribach, M. Humi, R. Lipton, K. Lurie, M. Sarkis</td>
</tr>
<tr>
<td>Applied Probability</td>
<td>A. C. Heinricher</td>
</tr>
<tr>
<td>Bayesian Statistics</td>
<td>M. Chen, B. Nandram</td>
</tr>
<tr>
<td>Calculus of Variations</td>
<td>R. Jordan, C. Larsen, R. Lipton, K. Lurie, B. Vernescu</td>
</tr>
<tr>
<td>Chemical Reaction Models</td>
<td>P. W. Davis, W. Farr</td>
</tr>
<tr>
<td>Combinatorics</td>
<td>P. R. Christopher, W. J. Martin, B. Servatius</td>
</tr>
</tbody>
</table>
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.

The minor consists of completion of at least 2 units of work, which must consist of

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:
   (a) Foundation Courses
   - MA 2073 Matrices and Linear Algebra II
   - MA 2611 Applied Statistics I
   - MA 2612 Applied Statistics II
   - MA 2631 Probability, or MA 3613 Probability for Applications
   - 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 other course numbered MA 540 through MA 559)

   (b) Upper-Level Courses
   - MA 2073 Matrices and Linear Algebra II
   - MA 2611 Applied Statistics I
   - MA 2612 Applied Statistics II
   - MA 2631 Probability, or MA 3613 Probability for Applications

2. Capstone Experience
The capstone experience usually consists of completion of MA 4658, Statistical Consulting. In this course, undergraduate students work with statistics faculty and graduate students to learn statistical practice and provide statistical advice to clients from the WPI community. Alternatively, students may arrange an independent study with one of the statistics faculty.

For information about the Statistics Minor, see any of the statistics faculty: Professors Joseph D. Petruccelli, Balgobin Nandram, Ming-Hui Chen, Hyunjoong Kim, Mijung Kim, or Ann H. Wiedie.
MECHANICAL ENGINEERING

G. TRYGGVASON, HEAD


ASSISTANT PROFESSORS: M. Demetriou, M. Fofana, S. S. Kohles

VISITING ASSISTANT PROFESSOR: E. C. Cobb

NORTON ASSOCIATE PROFESSOR: C. Demetry

NORTON RESEARCH PROFESSOR: R. N. Katz

PROFESSORS OF PRACTICE: S. Mirza


INTRODUCTION

Mechanical engineering uses the basic laws of the physical sciences, life sciences, the social science, and the humanities in their quest to serve mankind.

Airplanes, automobiles, trains, space vehicles, earth-moving equipment, nuclear reactors, plasma generators, heart-lung machines, miniature bearings, machines and machine tools, sewing machines, and power lawn mowers are but a few examples of the products with which mechanical engineering is associated.

Compared with other fields of engineering, mechanical engineering is the broadest in application as well as the most basic. Mechanical engineers design products, supervise production, conduct research and development, and manage businesses or technical operations. In addition, mechanical engineering requires persons who can use the sciences to devise useful products in an economic manner while minimizing the loss of our natural resources.

Looking forward to this wide range of possible careers, mechanical engineering students should get a sound foundation in mathematics and science. Plan a sequence of cultural and social studies, aim for a real understanding of the fundamentals of engineering, and achieve a proper balance between theory and application. A working knowledge of computers must be established through formal or informal learning processes. Inspection trips to industrial plants and COOP assignments are encouraged.

In this regard, the Mechanical Engineering Department offers extensive, modern, well-equipped facilities in the Higgins and Washburn Laboratories. These laboratories, covering the broad spectrum of mechanical engineering activities, are briefly described in the Resources available to Undergraduate Students section of this Catalog. They are widely used by the students enrolled in Mechanical Engineering and related programs.

GOAL

The Mechanical Engineering program at WPI is designed to develop graduates who can deal with real world situations that involve technological and humanistic/societal issues. Students develop literacy and competency in utilizing scientific and engineering methods for devising useful products in an economical way, while considering the impacts on society. The Mechanical Engineering program is in harmony with the WPI Plan philosophy of education, in which each student develops competence, confidence and the skill of self-learning.

OBJECTIVES

1. A graduate should be able to apply the fundamental principles of mathematics, science, and engineering to solve structured problems in mechanical engineering.
2. A graduate should be able to combine fundamental knowledge of engineering principles and modern techniques to solve realistic, unstructured problems that arise in mechanical engineering.
3. A graduate should demonstrate the ability to design and develop useful products, processes, or systems that benefit society.
4. A graduate should develop interpersonal skills, ethical behavior, a professional attitude and a respect for others to function effectively in a team environment.
5. A graduate should demonstrate communication skills, written, oral, electronic and graphical, so that they can perform engineering functions effectively.

OUTCOMES

Graduating students should demonstrate the following at a level equivalent to an entry-level engineer or first year graduate student:

a. An understanding of the fundamental principles of conservation laws, constitutive relations, mechanics and materials science.

b. The ability to apply mathematics, science and engineering to thermofluid and mechanical systems.

c. The ability to design a system, component or process to meet design criteria.

d. The ability to design and conduct experiments and to analyze and interpret the resulting data.

e. The ability to use modern engineering tools for engineering design and analysis.

f. The ability to communicate effectively both verbally and in writing.

g. The ability to function within multidisciplinary teams.

h. The ability to function professionally and ethically.

i. An understanding of contemporary issues and the impact of engineering solutions in a global/societal context.

j. An appreciation for the skills to accomplish life-long learning.

k. Knowledge of chemistry and calculus-based physics with depth in at least one.

l. The ability to apply advanced mathematics through multivariate calculus and differential equations.

m. Familiarity with statistics and linear algebra.
### 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 20), 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:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics and Basic Science</td>
<td>4</td>
</tr>
<tr>
<td>(Notes 1, 2, 3)</td>
<td></td>
</tr>
<tr>
<td>2. Engineering Science and Design</td>
<td>6</td>
</tr>
<tr>
<td>(includes MQP) (Notes 3, 4, 5, 6, 7, 8, 9)</td>
<td></td>
</tr>
</tbody>
</table>

**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. May include 1000 level courses only if designated ES or ME.
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 thermofluids 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.”

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 and additional 1/3 unit of course work in the area of Design to be taken in order to meet the ABET Capstone Design requirement.

### FUNDAMENTALS IN THE MAJOR

The WPI philosophy of education emphasizes the development of competence in students’ abilities in self-learning. In the context of the flexible WPI degree requirements and the breadth of the mechanical engineering profession, it is not possible—or beneficial—to specify a rigid educational pattern. Rather, each student, with advice, should develop a program that best meets personal and professional goals.

It is clear that the profession of mechanical engineering rests on a deep understanding of the concepts of science and mathematics. The distribution requirements establish the minimum framework for meeting the student’s educational goals.

**HUMANITIES/SOCIAL SCIENCES**

It is difficult for mechanical engineers to design systems without being literate in the disciplines making up the social sciences, for the concerns of people and the flow of capital—economies—are central to technological development. The questions of values and mankind’s cultural experiences as exemplified in the humanities are critical to the study of modern technology. More and more engineering students recognize the need for literacy in the humanities and social sciences, and the H&A Sufficiency and Social Sciences degree requirements are designed to meet this need. Mechanical engineering students are urged to work closely with their Sufficiency and Social Studies advisors as well as their academic advisor in the Mechanical Engineering Department to develop a program which meets their needs.

### DISCIPLINARY LITERACY

In addition to disciplinary literacy, the process of design and problem solving is best met by multidisciplinary, problem-oriented experiences. At WPI, projects and independent studies are best suited to this educational experience. It may be difficult to generalize as to whether the student should develop literacy in a particular area by course or project experiences. Courses are sometimes the optimum mode in developing a disciplinary background, while projects are often effective in multidisciplinary, problem-centered studies. Mechanical engineering students should design programs that take full advantage of both of these learning modes.

The academic program of the student should be designed to provide for a continuous development in the scientific and engineering areas, including analysis, design, and experimental studies. Students are urged to take the Fundamentals of Engineering Examination, the first step toward becoming a registered professional engineer (P.E.), at the earliest opportunity.
STUDENTS EARNING A B.S. DEGREE IN MECHANICAL ENGINEERING MUST COMPLETE 15 UNITS OF STUDY, DISTRIBUTED AS FOLLOWS:

<table>
<thead>
<tr>
<th>4 UNITS OF NON-TECHNICAL ACTIVITIES</th>
<th>2 UNITS H&amp;A SUFICIENCY</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>
</tr>
<tr>
<td></td>
<td>1/3 UNIT PHYSICAL EDUCATION</td>
<td>See WPI Requirements</td>
</tr>
</tbody>
</table>

1 UNIT FREE ELECTIVE

<table>
<thead>
<tr>
<th>1 UNIT FREE ELECTIVE</th>
</tr>
</thead>
</table>

4 UNITS OF MATHEMATICS AND BASIC SCIENCE

| 4/3 Units Student Selected Courses from the General Category of Mathematics and/or Basic Science |

5/3 Units
Differential & Integral Calculus and Ordinary Differential Equations

<table>
<thead>
<tr>
<th>3/3 Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Chemistry and Two Physics, OR One Physics and Two Chemistry</td>
</tr>
</tbody>
</table>

5/3 Units
Differential & Integral Calculus and Ordinary Differential Equations

<table>
<thead>
<tr>
<th>3/3 Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Chemistry and Two Physics, OR One Physics and Two Chemistry</td>
</tr>
</tbody>
</table>

6 UNITS OF MECHANICAL ENGINEERING (Notes 1 & 2)

<table>
<thead>
<tr>
<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>
</tr>
</thead>
<tbody>
<tr>
<td>MECHANICAL SYSTEMS</td>
<td>THERMAL SYSTEMS</td>
<td>OTHER COURSES</td>
<td>MAJOR QUALIFYING PROJECT (MQP)</td>
<td>ELECTIVES</td>
</tr>
<tr>
<td>ES 2501</td>
<td>ES 3001</td>
<td>ES 2001</td>
<td></td>
<td>At least one unit must be chosen as ES or ME courses at the 4000-level.</td>
</tr>
<tr>
<td>ES 2502</td>
<td>ES 3003</td>
<td>ES 3601</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ES 2503</td>
<td>ES 3004</td>
<td>ES 3901</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Linear Algebra</th>
<th>Statistics</th>
<th>Mechanical System Design</th>
<th>Thermal System Design</th>
<th>Realization</th>
<th>Capstone Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA 2071 ME 3501</td>
<td>MA 2611</td>
<td>ME 3310 ME 4320</td>
<td>ME 4429</td>
<td>ES 3323</td>
<td>ME 4320</td>
</tr>
<tr>
<td>MA 2073 ME 3512</td>
<td>MA 2612</td>
<td>ME 3311 ME 4430</td>
<td>ME 4430</td>
<td>ME 1800</td>
<td>ME 4429</td>
</tr>
<tr>
<td>MA 4411 ME 4505</td>
<td>MA 3613</td>
<td>ME 3320 ME 4770</td>
<td>ME 4770</td>
<td>ME 2300</td>
<td>ME 4430</td>
</tr>
<tr>
<td>ME 3311 ME 4530</td>
<td>ME 3825</td>
<td>ME 3506 ME 4816</td>
<td>MQP (depending on topic)</td>
<td>ME 3506</td>
<td>ME 4770</td>
</tr>
<tr>
<td>ME 3321 ME 4605</td>
<td>ME 3901</td>
<td>MQP (depending on topic)</td>
<td>MQP (depending on topic)</td>
<td>MQP (depending on topic)</td>
<td>ME 4816</td>
</tr>
</tbody>
</table>

Note 2: Elective courses from other engineering disciplines may also be selected at the 2000, 3000 or 4000 levels.
AREAS IN WHICH COMPETENCE SHOULD BE DEVELOPED

The academic program of mechanical engineering students typically progresses from mathematics and basic science in the earliest years, through the engineering sciences, and then to analysis, design and experimentation. An operational capability in the use of computers must be acquired early in students’ programs, as well as an overall skill in graphic, oral, and written communications. Humanities and arts and social science studies are essential in the program. When applicable, advanced placement from high schools will be given appropriate credit and noted on the WPI transcript.

MATHEMATICS AND BASIC SCIENCES

It is essential that mechanical engineering students establish a solid foundation in mathematics, the fundamental language of engineers. It is recommended that mechanical engineering students develop competence, as a minimum, in calculus and differential equations through such courses as: MA 1021, MA 1022, MA 1023, MA 1024, MA 2051. Additional courses are desirable and should be selected in consultation with the student’s academic advisor as preparation for advanced-level course and project work.

An adequate background in the basic sciences is mandatory for mechanical engineering students and typically includes physics, chemistry, and other sciences. Programs should be planned so that topics related to mechanics, energy, heat, light, sound, optics, and electricity are covered in preparation for the material to be studied in the engineering sciences. Students, in consultation with their advisors, are urged to include in their programs courses from the following list which support their technical interest:

- MA 2051
- MA 1021, MA 1022, MA 1023, MA 1024, MA 2051
- Additional courses as: MA 1021, MA 1022, MA 1023, MA 1024, MA 2051.

Mathematics and basic sciences must include a minimum of four units, include both chemistry and physics with a minimum of two courses in either, and include differential and integral calculus and differential equations.

ENGINEERING SCIENCE AND DESIGN

For mechanical engineering students, the engineering science and design will normally require the equivalent of a year and a half of full-time study. In the engineering sciences, graphics; mechanics of solids, including stress analysis and dynamics; thermodynamics; fluid and continuum mechanics; materials science; and materials processing provide a background for the higher-level experiences. Students must also develop competence in closely-related engineering and science areas, such as electrical engineering, control engineering, computer science, and heat and mass transfer. A partial listing of engineering science courses of direct interest to the mechanical engineering student follows: ES 1310, ES 2001, ES 2501, ES 2502, ES 3001, ES 3002, ES 3003, ES 3004, ES 3011, ES 3323, ME 3501, ES 2502, ME 3502, ME 3505, EE 2001, EE 2002, EE 3601, and ES 2011/NE 2011.

With mastery of the basic and engineering sciences, mechanical engineering students are in a strong position to utilize the tools of their profession for the gaining of new knowledge and the solution of significant real-world problems, often termed “design.” Their MQP and IQP enable them to specialize in a given area of mechanical engineering in an interdisciplinary setting.

Engineering design is the decision-making experience of an engineer in which the combination of the basic sciences, engineering sciences and mathematics is applied, with judgment, to use resources economically to meet stated objectives. The development of literacy and skill in design may include the establishment of objectives, criteria, synthesis, analysis, construction, experimentation, evaluation, and communication. Students should consult their advisors in selecting appropriate courses, projects and independent studies to meet their design requirements. Programs include the equivalent of at least one-half year of a design experience and often involve courses such as ME 2300, ME 3310, ME 3311, ME 3320, ME 3321, ME 4320, and ES 3323 plus the Major and Interactive Qualifying Projects along with independent study. Advanced design courses are available if a student decides to do in-depth study in this area. A minimum of six units of engineering science/design is required, and subdivided between engineering science and design on a 2:1 basis.

The one unit energy stem requirement is normally satisfied by taking courses such as ES 3001, ES 3003, and ES 3004. The one unit mechanical systems stem requirement is normally satisfied by taking courses such as ES 2501, ES 2502, ES 2503, and ME 3320.

Field trips and professional society activities are encouraged as they enhance overall professional perspectives.

MECHANICAL ENGINEERING DEPARTMENT CONCENTRATIONS

After developing competence in the basic engineering and science areas, mechanical engineering students are encouraged to select courses and projects in line with their personal and professional interests.

For those students that have an interest in pursuing upper-level courses (see the Mechanical Engineering Program Chart) and suitable MQP, early and continuing consultation with their academic advisors is encouraged to ensure that suitable preliminary work is completed on an appropriate schedule.

For those students that have an interest in pursuing upper-level activities within a narrow area of mechanical engineering, the Department offers seven specialty areas in which a “Concentration” may be earned. Each requires completion of six courses specified by that area, plus an MQP in that area. A brief description of each Concentration area, the name of a faculty member well versed in all phases of that area, and the particular course options and requirements are noted in the Mechanical Engineering Concentrations chart.

Students should note that they may utilize graduate courses if they are appropriate. The academic advisor must approve the course in advance. Integrated undergraduate-graduate programs are encouraged.
MECHANICAL ENGINEERING DEPARTMENT CONCENTRATIONS

AEROSPACE ENGINEERING (GATSONIS)
Students are provided with ample opportunity to develop technical competence in lightweight structures, low- and high-speed aerodynamics, microgravity dynamics, propulsion systems, and space systems from a design, analysis, and synthesis point of view. Facilities at WPI, including wind tunnels, are available for experimental work.

Typical MQP activities include the analysis, design, construction, and/or testing of flight vehicles, satellites, or components.

<table>
<thead>
<tr>
<th>Aerospace</th>
<th>2 Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 2713 Astronautics</td>
<td></td>
</tr>
<tr>
<td>ME 5711 Aerodynamics</td>
<td></td>
</tr>
<tr>
<td>Select 4</td>
<td></td>
</tr>
<tr>
<td>ME 3410 Flow of Compressible Fluids</td>
<td></td>
</tr>
<tr>
<td>ME 3714 Propulsion I</td>
<td></td>
</tr>
<tr>
<td>ME 4605 Computational Fluid Mechanics</td>
<td></td>
</tr>
<tr>
<td>ME 4712 Supersonic Aerodynamics</td>
<td></td>
</tr>
<tr>
<td>ME 4715 Aerospace Structures</td>
<td></td>
</tr>
<tr>
<td>ME 4724 High Speed Flow</td>
<td></td>
</tr>
<tr>
<td>ME 4770 Aerospace Systems Design</td>
<td></td>
</tr>
<tr>
<td>*Plus Aerospace MQP</td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Biomechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select 2 Biology and Biotechnology (BB) Courses:</td>
</tr>
<tr>
<td>Preferred choices include:</td>
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<tr>
<td>BB 2550 Cell Biology</td>
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<tr>
<td>BB 3110 Animal Physiology</td>
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<tr>
<td>BB 3130 Anatomy</td>
</tr>
<tr>
<td>Select 4</td>
</tr>
<tr>
<td>ME 3501 Elementary Continuum Mechanics</td>
</tr>
<tr>
<td>ME 3506 Rehabilitation Engineering</td>
</tr>
<tr>
<td>ME 4504 Biomechanics</td>
</tr>
<tr>
<td>ME 4606 Biofluids</td>
</tr>
<tr>
<td>ME 4814 Biomedical Materials</td>
</tr>
<tr>
<td>Any BE course at the 3000-level or higher</td>
</tr>
<tr>
<td>* Plus Biomechanical-related MQP</td>
</tr>
</tbody>
</table>

ENGINEERING MECHANICS (RENCIS)
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.

<table>
<thead>
<tr>
<th>Engineering Mechanics</th>
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<tbody>
<tr>
<td>Select 6</td>
</tr>
<tr>
<td>ME 3023 Mech. Behavior &amp; Modeling Properties of Eng’g Mat’ls</td>
</tr>
<tr>
<td>ME 3501 Elementary Continuum Mechanics</td>
</tr>
<tr>
<td>ME 3502 Advanced Stress Analysis</td>
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<tr>
<td>ME 3505 Mechanical Vibrations</td>
</tr>
<tr>
<td>ME 3506 Rehabilitation Engineering</td>
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<tr>
<td>ME 3512 Introduction to the Finite Element Method</td>
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<tr>
<td>ME 3602 Intermediate Fluid Dynamics</td>
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<tr>
<td>ME/BE 4504 Biomechanics</td>
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<tr>
<td>ME 4505 Advanced Dynamics</td>
</tr>
<tr>
<td>ME 4520 Analytical Methods in Mechanical Engineering</td>
</tr>
<tr>
<td>ME 4530 Computational Methods in Mechanical Engineering</td>
</tr>
<tr>
<td>* Plus Engineering Mechanics MQP</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Mechanical Design</th>
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<tbody>
<tr>
<td>2 Required</td>
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<tr>
<td>ME 3310 Kinematics of Mechanisms</td>
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<tr>
<td>ME 3320 Design of Machine Elements</td>
</tr>
<tr>
<td>Select 4</td>
</tr>
<tr>
<td>ES 1310 Engineering Design Graphics</td>
</tr>
<tr>
<td>ES 3323 Introduction to CAD</td>
</tr>
<tr>
<td>ME 2300 Introduction to Engineering Design</td>
</tr>
<tr>
<td>ME 3311 Dynamics of Mechanisms and MAchines</td>
</tr>
<tr>
<td>ME 3321 Dynamic Modeling</td>
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<tr>
<td>ME 3506 Rehabilitation Engineering</td>
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<tr>
<td>ME 4320 Advanced Engineering Design</td>
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<tr>
<td>ME 4815 Industrial Robotics</td>
</tr>
<tr>
<td>ME 4816 Materials Optimization for Engineers</td>
</tr>
<tr>
<td>* Plus Mechanical Design MQP</td>
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</tbody>
</table>
MANUFACTURING (BROWN)
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, FEM, composite materials, factory automation, materials processing.
www.wpi.edu/+MFE
See also the Manufacturing Systems engineering degree program.

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.

THERMAL/FLUID ENGINEERING (SAVILONIS)
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.

Manufacturing
Select 2
ME 1800 Materials Selection and Manufacturing Processes
ME 2820 Materials Processing
ME 4816 Materials Optimization for Engineers
ME 4822 Solidification Processing
Select 2
ES 3011 Control Engineering I
ME 3820 Computer-Aided Manufacturing
ME 4815 Industrial Robotics
Select 2
MG 2500 Management Science I: Deterministic Decision Models
MG 2850 Engineering Economics
MG 3400 Production System Design
MG 3401 Production Planning and Control
* Plus Manufacturing MQP

Materials Science
Select 2
ME 2820 Materials Processing
ME 4816 Materials Optimization for Engineers
ME 4822 Solidification Processing
Select 2
ME 3023 Mech. Behavior and Modeling Properties of Eng’g Mat’ls
ME 3811 Structure of Materials
ME 3825 Mechanical Behavior of MAterials Laboratory
ME 4813 Ceramics
ME 4814 Biomedical Materials
ME 4821 Chemistry, Properties, and Processing of Plastics
ME 4832 Corrosion and Corrosion Control
Select 2
ME 4840 Phase Transformation
ME 4850 Thermodynamics of Materials
ME 583 Analytical Methods in Materials Engineering
* Plus Materials Science MQP

Thermal-Fluids
Select 6
ME 3410 Compressible Flow
ME 3422 Environmental Issues and Analysis
ME 3714 Propulsion I
ME 4412 Introduction to Combustion
ME 4429 Thermodynamic Applications and Design
ME 4604 Fluid Mechanics of Machines
ME 4605 Computational Fluid Mechanics
ME 4606 Biofluids
ME 4724 High Speed Flow
* Plus Thermal-Fluids 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

BS-MS 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 COOP Program provides an opportunity to integrate “real-world” experience into an educational program. Details are found in the COOPERATIVE EDUCATION PROGRAM section of this catalog.

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.

MECHANICAL ENGINEERING COURSES

<table>
<thead>
<tr>
<th>Aerospace Engineering</th>
<th>Category</th>
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<tbody>
<tr>
<td>ME 2713 Astronautics</td>
<td>I</td>
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<tr>
<td>ME 3711 Aerodynamics I</td>
<td>I</td>
</tr>
<tr>
<td>ME 3714 Propulsion</td>
<td>I</td>
</tr>
<tr>
<td>ME 4712 Supersonic Aerodynamics</td>
<td>II</td>
</tr>
<tr>
<td>ME 4715 Aerospace Materials and Design</td>
<td>I</td>
</tr>
<tr>
<td>ME 4724 High Speed Flow</td>
<td>I</td>
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<tr>
<td>ME 4770 Aerospace Systems Design</td>
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<tr>
<th>Engineering Experimentation</th>
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<tr>
<td>ME 3901 Engineering Experimentation</td>
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<tr>
<th>Engineering Mechanics</th>
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<tbody>
<tr>
<td>ES 2501 Introduction to Static Systems</td>
</tr>
<tr>
<td>ES 2502 Stress Analysis</td>
</tr>
<tr>
<td>ES 2503 Introduction to Dynamic Systems</td>
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<tr>
<td>ME 1520 Mechanics of Alpine Skiing</td>
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<tr>
<td>ME 3501 Elementary Continuum Mechanics</td>
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<tr>
<td>ME 3502 Advanced Mechanics of Materials</td>
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<tr>
<td>ME 3505 Mechanical Vibrations</td>
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<tr>
<td>ME 3506 Rehabilitation Engineering</td>
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<tr>
<td>ME 3512 Introduction to the Finite Element Method</td>
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<tr>
<td>ME 3023 Mechanical Behavior and Modelling Properties of Engineering Materials</td>
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<tr>
<td>ME/BE Biomechanics</td>
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<thead>
<tr>
<th>Manufacturing Engineering</th>
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<tbody>
<tr>
<td>ME 1800 Material Selection and Manufacturing Processes</td>
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<td>ME 2820 Materials Processing</td>
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<tr>
<td>ME 3820 Computer-Aided Manufacturing Engineering</td>
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<tr>
<td>ME 4815 Industrial Robotics</td>
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<tr>
<th>Materials Science and Engineering</th>
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<tbody>
<tr>
<td>ES 2001 Introduction to Material Science</td>
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<tr>
<td>ME 3023 Mechanical Behavior and Modeling Properties of Engineering Materials</td>
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<tr>
<td>ME 3811 Microstructure Analysis and Control</td>
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<tr>
<td>ME 3825 Mechanical Metallurgy Laboratory</td>
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<tr>
<td>ME 4813 Ceramics</td>
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<tr>
<td>ME/BE Biologics</td>
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<tr>
<th>Mechanical Design</th>
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<tr>
<td>ES 1310 Engineering Design Graphics</td>
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<td>ME 4320 Advanced Engineering Design</td>
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<tr>
<th>Thermal/Fluid Engineering</th>
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<tr>
<td>ES 3000 Classical Thermodynamics</td>
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<tr>
<td>ES 3001 Introduction to Thermodynamics</td>
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<tr>
<td>ES 3003 Heat Transfer</td>
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<tr>
<td>ES 3004 Fluid Mechanics</td>
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<tr>
<td>ME 3410 Compressible Flow</td>
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<tr>
<td>ME 3422 Environmental Issues and Analysis</td>
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<tr>
<td>ME 3602 Intermediate Fluid Dynamics</td>
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<tr>
<td>ME 4412 Introduction to Combustion</td>
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<td>ME 4429 Thermofluid Applications and Design</td>
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<td>ME 4604 Fluid Mechanics of Machines</td>
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<td>ME 4605 Computational Fluid Mechanics</td>
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<td>ME/BE Biofluids</td>
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<tr>
<th>Special Topics</th>
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<tbody>
<tr>
<td>ME 4010 Seminar</td>
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<tr>
<td>IS 4 ME Special Topics</td>
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</table>

Independent study topics in mechanical engineering may be arranged. Consult faculty in the specific technical area for details.
INTRODUCTION

Army Reserve Officer Training Corps (ROTC) is offered by WPI and is available to all male and female students. Physically qualified American citizens who complete the entire four-year program, concurrent with baccalaureate degree completion, may be commissioned in the United States Army, Army Reserve or Army National Guard. Emphasis throughout is on the development of individual leadership abilities and preparation of the student for a lifetime of service to the nation. The Military Science Department offers several concurrent programs designed to complement the WPI Plan. There are two variations of ROTC available to students who desire to participate: 1. The four-year program is an on-campus program during which students participate in required military science courses and activities. Students attend a six-week advanced training camp (with pay) between the third and fourth year for practical application of classroom instruction. 2. The two-year ROTC program begins with a six-week basic summer training camp (with pay). Upon successful completion of basic camp, the student enters the third year of ROTC and will attend the advanced camp during the following summer. As another alternative, an enlisted member of the Armed Forces, who has completed Basic Training can qualify for the two year ROTC program and the Simultaneous Membership Program.

All military science courses are open to any interested student without incurring any military obligation. Military science courses are an excellent medium for personal enrichment and development of leadership abilities.

BASIC COURSE

The Basic Course includes classroom instruction and practical application opportunities which introduce the student to the Army and the Army to the student. Since all effective leaders must understand the organization in which they will function, initial instruction is intended to create a working knowledge of the Army. Subsequent instruction deals with the study of military leadership, management, and technical proficiency.

ADVANCED COURSE

The Advanced Course includes classroom instruction and practical application opportunities taught during the third and fourth years. The objective is to develop leaders; to give the cadet experience in first organizing, then managing a project; to enable the cadet to take charge of any project and to bring it to a successful conclusion. This acquired ability is useful in every human endeavor; it is essential to the military leader. In conjunction with the theoretical approach to leadership studied in class, students are required to apply their knowledge during Leadership Laboratories. The Advanced Course is open to all students who have satisfactorily completed two years in the basic course or the equivalent.

A student enrolled in the Advanced Course receives an allowance of $150 per month, tax free, each month in school. Pay during the Advanced Camp, is as set by Congressional legislation. To enroll in the Advanced Course, students must execute a contract stating they will continue the course of instruction for two years and accept the commission of Second Lieutenant in the United States Army, Army Reserve or Army National Guard upon graduation.

PROFESSIONAL MILITARY EDUCATION

The required professional military education component encompasses the full four years of study. It consists of two essential parts: 1. completion of a baccalaureate degree; 2. undergraduate certification in the areas of written communications, military history, and computer literacy.

LEADERSHIP LABORATORY

Leadership Laboratory consists of a monthly four-hour practical exercise in leadership or military skills. It is an integral part of the annual ROTC program. The purpose of Leadership Laboratory is to give each cadet the opportunity to apply practically the theory learned during formal class periods. The senior cadets conduct the laboratory period with underclass students filling subordinate roles; level of responsibility depends upon how far they have advanced in ROTC.

The Military Science Department encourages its cadets to participate in athletics and to join other extracurricular activities in order to practice leadership theories learned in military science.
MILITARY SCIENCE COURSE FLOW CHART

MSI
MS 1051
MS 1061
MS 1071
MS 1081

MSII
MS 2051
MS 2061
MS 2071
MS 2081

MSIII
MS 3051
MS 3061
MS 3071
MS 3081

MSIV
MS 4051
MS 4061
MS 4071
MS 4081

WPI COURSE STUDY

WPI COURSE STUDY

WPI COURSE STUDY

WPI COURSE STUDY

WPI DEGREE & ARMY COMMISSION

(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.
PHYSICAL EDUCATION

R. R. GILBERT, HEAD
ASSOCIATE PROFESSORS: P. J. Grebinar

REQUIREMENTS
Qualification in physical education shall be established by completing 1/3 unit of course work or its equivalency. Students are urged to complete this requirement in their first two years of residency at WPI. Such an equivalency may be satisfied through the PE 1100 series. PE 1100 is designed for students who wish to obtain PE credit through any of five different categories as listed below and may be substituted for any 1/12 unit PE course:

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 head of the Physical Education Department is necessary.
4. Individualized program at WPI; advance approval by the head of the Physical Education Department is necessary.
5. Proficiency testing is available in some areas; arrangements should be made with a Physical Education Department instructor.

Students who wish to obtain PE credit by the above means must be enrolled in a course in the PE 1100 series. No student may use any 1/12-unit PE courses beyond the four required 1/12 unit to satisfy any other requirement.

Participation in certain ROTC programs may entitle students to a waiver of the PE requirement.

ATHLETIC PROGRAMS

THE INTERCOLLEGIATE PROGRAM
The intercollegiate athletics program offers competition in 21 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 classes, in the afternoon. 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.

THE CLUB SPORTS PROGRAM
The Club Sports Program offers a variety of competitive activities for student participation. Most of the Club Sports listed below compete against teams from other institutions.

Club Sports
Alpine Skiing
Cheerleaders
Coed Soccer
Fencing
Free Style Wrestling
Ice Hockey
Lacrosse (men/women)
Martial Arts (SOMA)
Rugby
Scuba
Ultimate Frisbee
Volleyball (men)
Water Polo

Club Sports, Class II, are administered through the Department of Physical Education 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, volleyball, cross-country, basketball, swimming, soccer, water polo, softball, bowling, table tennis, and track. 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 in the Director of Intramurals located in Alumni Gym.
PHYSICS

T. H. KEIL, HEAD
ASSOCIATE PROFESSORS: P. K. Aravind, N. A. Burnham, R. S. Quimby
ASSISTANT PROFESSORS: G. S. Iannacchione, S. W. Pierson, L. C. Lew Yan Voon, A. A. Zozulya

GOALS OF WPI’S UNDERGRADUATE PROGRAM
IN PHYSICS
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.

SPECIFIC EDUCATIONAL OBJECTIVES OF THE PHYSICS PROGRAM:
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.

INTRODUCTION
Ask a physicist what physics has to do with, and you are likely to be told: “Everything!” Though oversimplified, this answer does contain a kernel of truth. In their study of nature, physicists concern themselves with interactions involving matter and energy of every form.

Physicists’ interests range from the tiny world of subatomic particles to stars, galaxies and the vast cosmic sea of space and time in which they travel. They have developed intricate tools to assist the human senses in probing these remote extremes of our natural environment. They have distilled their understanding of nature into laws of great generality and elegance, from the mathematical patterns needed to interpret the perfect symmetry and the regularity of atoms and crystals, to the powerful mathematical treatment of chaos and disorder needed to deal with the concept of heat.

Of course, not all physicists work at the very limits of our knowledge of nature. Many use their understanding of physics to develop practical applications that solve more familiar human problems. The pioneering work on semiconductors in the 1940s led to the development of computers, transistor radios and a communication network that is bringing the peoples of the world ever closer together. The laser, invented in the 1960s, has been used in such varied applications as eye surgery and radar, and even in computerized cash registers. The list of problems solved is long; the list of future possibilities is endless. So there is some truth in the statement that “physics has to do with everything.”

One of the distinguishing characteristics of the physicist’s approach is a cyclical growth pattern. Systematic experiments provide new facts. New theory is developed to summarize these facts and make them manageable. The new theory has as its consequences practical applications and new questions, leading to new experimentation. Along the way, physicists are guided by certain fundamental principles such as symmetry, continuity and conservation laws.

Students come to the study of physics from many backgrounds and for many reasons. Two aspects in particular seem to attract them. The first is the opportunity to choose from a wide range of intriguing subjects of study, both theoretical and experimental, both fundamental and applied. The second is the combination of intuitive ideas and the penetrating style of logical and mathematical problem-solving which students come to realize physics “has to do with.”

CAREER OPPORTUNITIES IN PHYSICS
Undergraduate physics programs were once formulated with the expectation that graduating students would enter postgraduate programs, where they would earn an advanced degree under the guidance of a practicing physicist. The long-term career objective was assumed to be a permanent position in an academic physics department, with interests divided between scientific research and teaching. Although this traditional outlook is still valid for many students entering the study of physics today, the unprecedented worldwide growth of science-based industries has led to exciting new career opportunities involving pure physics mixed with engineering and applied science. Many technically oriented students have also a deep interests in pure science; they are attracted to applied physics because it allows them to satisfy their scientific curiosity while at the same time pursuing the practical objectives of an engineer. In recognition of this new career choice the physics department offers a degree in engineering physics in addition to the traditional physics program. As shown in the sample programs below, students for this degree have great freedom to shape their program to match their individual interests.
AREAS OF FACULTY INTEREST
(PROJECT AND INDEPENDENT STUDIES)

P. Aravind  Quantum optics, quantum mechanics, group theory.
N. Burnham  Atomic force microscopy, nanomechanics
G. Iannacchione  Calorimetry, liquid crystals
S. Jasperson  Optical properties of solids, optical instruments.
T. Keil  Solid state physics, mathematical physics, fluid mechanics.
L. Lew Yan Voon  Solid state physics, semiconductors
D. Nelson  Optical and transport properties, solid state physics, lattice dynamics.
G. Phillies  Light scattering spectroscopy, complex fluids, biochemical physics.
S. Pierson  Statistical mechanics, super conductivity.
R. Quimby  Optical properties of solids, laser spectroscopy.
L. Ram-Mohan  Field theory, many body problems, solid state physics, linear and non-linear optical properties of semiconductors, computational physics.
G. Swartzlander  Optical solitons, nonlinear optics.
A. Walther  Optics, optical instruments, precision measurements.
A. Zozulya  Non-linear optics, photo-refractive materials

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 20), completion of a minimum of 10 units of study is required in the areas of mathematics, physics, and related fields as follows:

PHYSICS Requirements  Minimum Units
1. Mathematics (Note 1)  3
2. Physics (including the MQP; may include ES 3001) (Note 2)  5
3. Other subjects to be selected from mathematics, science, engineering, computer science, and management (Note 2)  2

Notes:
1. Mathematics must include at least 2/3 unit of mathematics at the level of MA 3000 or higher.
2. Either item 2 or 3 must include 1/3 unit of PH 2600, PH 3600, or other laboratory course approved by the department Program Review Committee following petition by the student.

ENGINEERING PHYSICS
1. Same requirements as PHYSICS, with the addition that the 10 units must include 2 units of coordinated engineering and other technical/scientific activities. The 2-unit program must be formulated prior to final year of study by student in consultation with the academic advisor, and must be certified prior to the final year by the departmental Program Review Committee.

Curriculum Outline — Physics and Engineering-Physics

The programs of study described below are designed to fulfill the needs and interests of students over the range from “pure” to “applied,” or “engineering” science. They are designed to provide, first of all, a foundation in the indispensable principles and techniques of classical and modern physics. Such preparation is necessary and appropriate for any future in science and technology, including that of postgraduate study and research. Moreover, insofar as appropriate within an undergraduate curriculum, programs are offered which allow options of special experience in some of the active areas of applied or engineering physics.

All programs include a common group of recommended core courses which provide the foundation, beginning with the great themes of physics—matter, motion, forces, energy, and the nature and concepts of electricity and magnetism. They build on that basic knowledge and perspective together with progressively more sophisticated mathematical techniques. Beyond this essential core, a student may choose either a more traditional program of physics study or one relating to an area of individual interest with engineering applications. Illustrations of these options are outlined in the section below, “Physics and Engineering-Physics Programs.”

Guidance in the planning of students’ programs will be provided by academic advisors. A departmental engineering-physics coordinator is also available for consultation by students and academic advisors on questions pertaining to curriculum and project matters.

In addition to the courses, the Major Qualifying Project (MQP) has the potential to provide valuable experience and to broaden students’ perspectives in the chosen subject area—this is one of the exceptional opportunities uniquely associated with the WPI Plan. In the case of students concentrating in one of the engineering-physics fields, the project topic would be chosen for its relevance to that area of interest. Additional information about the MQP is presented in the section on page 139, “Project Opportunities in Physics and Engineering-Physics.”

Students who feel that their interests and objectives do not fit naturally into any of the illustrative programs presented here are invited to consult with their academic advisors and with representatives of the Physics Department. It is usually possible to adapt a program to their individual needs.

PHYSICS AND ENGINEERING-PHYSICS PROGRAMS

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
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

<table>
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<tr>
<th>Course Code</th>
<th>Course Name</th>
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<tbody>
<tr>
<td>PH 3402</td>
<td>Quantum Mechanics II</td>
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<tr>
<td>PH 4201</td>
<td>Advanced Classical Mechanics</td>
</tr>
<tr>
<td>PH (IS/P)</td>
<td>Selected Readings in Physics</td>
</tr>
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Related Courses

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<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>EE 2311</td>
<td>Continuous-Time Signal and System Analysis</td>
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<tr>
<td>EE 2312</td>
<td>Discrete-Time Signal and System Analysis</td>
</tr>
<tr>
<td>EE 3801</td>
<td>Logic Circuits</td>
</tr>
<tr>
<td>EE 3901</td>
<td>Semiconductor Devices</td>
</tr>
<tr>
<td>ES 3011</td>
<td>Control Engineering I</td>
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<tr>
<td>PH 3117</td>
<td>Problem Solving Seminar</td>
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<tr>
<td>PH 3501</td>
<td>Relativity</td>
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<tr>
<td>PH 3502</td>
<td>Solid State Physics</td>
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<tr>
<td>PH 3503</td>
<td>Nuclear Physics</td>
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<tr>
<td>PH 3504</td>
<td>Optics</td>
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<tr>
<td>PH (IS/P)</td>
<td>Modern Optics</td>
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<tr>
<td>PH 501 (Graduate)</td>
<td>Mathematical Methods of Physics</td>
</tr>
<tr>
<td>PH 511 (Graduate)</td>
<td>Classical Mechanics</td>
</tr>
<tr>
<td>MA 4291</td>
<td>Applicable Complex Variables</td>
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2. Computational Physics.

Recommended Courses

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<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>MA 3255</td>
<td>Numerical Analysis I</td>
</tr>
<tr>
<td>MA 4411</td>
<td>Numerical Solutions of Differential Equations</td>
</tr>
<tr>
<td>PH (IS/P)</td>
<td>Numerical Techniques in Physics</td>
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Related Courses

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<tbody>
<tr>
<td>PH 3117</td>
<td>Problem Solving Seminar</td>
</tr>
<tr>
<td>PH 3402</td>
<td>Quantum Mechanics II</td>
</tr>
<tr>
<td>PH 3502</td>
<td>Solid State Physics</td>
</tr>
<tr>
<td>PH 501/2</td>
<td>(Graduate) Mathematical Physics</td>
</tr>
<tr>
<td>MA 4255</td>
<td>Numerical Analysis II</td>
</tr>
<tr>
<td>MA 4291</td>
<td>Applicable Complex Variables</td>
</tr>
<tr>
<td>CS 1005</td>
<td>Introduction to Programming</td>
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<tr>
<td>CS 2005</td>
<td>Techniques of Programming</td>
</tr>
<tr>
<td>CS 3011</td>
<td>Introduction to Computer Organization and Assembly Language</td>
</tr>
<tr>
<td>CS 4731</td>
<td>Computer Graphics</td>
</tr>
<tr>
<td>EE 2311</td>
<td>Continuous-Time Signal and System Analysis</td>
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<tr>
<td>EE 2312</td>
<td>Discrete-Time Signal and System Analysis</td>
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<tr>
<td>EE 3801</td>
<td>Logic Circuits</td>
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<tr>
<td>ES 3011</td>
<td>Control Engineering I</td>
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3. Optics

Recommended Courses

<table>
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<tr>
<th>Course Code</th>
<th>Course Name</th>
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<tbody>
<tr>
<td>PH 3504</td>
<td>Optics</td>
</tr>
<tr>
<td>PH (IS/P)</td>
<td>Photonics</td>
</tr>
<tr>
<td>PH (IS/P)</td>
<td>Selected Readings in Optics</td>
</tr>
</tbody>
</table>
Related Courses
PH 3117 Problem Solving Seminar
PH 3402 Quantum Mechanics II
PH 3502 Solid State Physics
PH 542/3 (Graduate) Modern Optics I and II
MA 4291 Applicable Complex Variables
ID 3150 Light, Vision, and Understanding
EE 2311 Continuous-Time Signal and System Analysis
EE 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 3117 Problem Solving Seminar
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
EE 2311 Continuous-Time Signal and System Analysis
EE 2312 Discrete-Time Signal and System Analysis
ES 3011 Control Engineering I

5. Nuclear Science And Engineering

Recommended Courses
NE 2001 Introduction to Nuclear Technology
NE 2002 Introduction to Health Physics
PH 3503 Nuclear Physics

Related Courses
PH 3117 Problem Solving Seminar
PH 3402 Quantum Mechanics II
PH 3501 Relativity
PH 3503 Nuclear Physics
PH 3504 Optics
PH 533 (Graduate) Nuclear Physics
NE 3101 Nuclear Reactor Principles
NE 3201 Radioisotope Methodology
NE 3301 Radiation Transport
ME 4832 Corrosion and Corrosion Control
EE 3801 Logic Circuits
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
PH 3117 Problem Solving Seminar
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

Project Opportunities in Physics and Engineering-Physics

Opportunities for physics students to participate in theoretical, computer-aided or experimental research exist in numerous fields, including nuclear and particle physics, modern and classical optics, statistical and solid-state physics, electromagnetism, astrophysics, field theories, and in the great range of subfields within these categories.

In the engineering-physics programs, the MQP subject is generally chosen for its relevance to the particular area of concentration. Students usually obtain the assistance of their academic advisors and of the engineering-physics coordinator in arranging the project. It may also include the participation of a project coadvisor who is a member of the engineering faculty.

Information for the selection of a Major Qualifying Project (MQP) by physics and engineering-physics students can be obtained from physics faculty members at any time during the academic year, and especially during the Term C project planning period. A project resource booklet, available in the department office, provides MQP subject information, identification of participating faculty and their areas of interest, and data relating to past projects. Physics faculty serve as project advisors on MQPs in their own fields of research, and sometimes in other appropriate scientific areas of mutual student-advisor interest.

For all physics and engineering-physics students, there are opportunities for off-campus projects in industries, hospitals, research institutions, government and other resources in the Worcester vicinity and beyond. Information on these possibilities, which are constantly changing and expanding, is managed and made available to students and faculty by the WPI Project Center.

Physics for Nonphysics Majors

Physics is the scientific underpinning for all engineering work and is therefore considered by prospective engineers, almost without exception, to be a subject which merits serious study. The elementary physics sequence at WPI encompasses the subject areas of classical mechanics (PH 1110/PH 1111), electricity and magnetism (PH 1120/PH 1121), 20th century physics (PH 1130), and oscillation and wave phenomena (PH 1140). The sequence is designed to be taken either in the pattern PH 1110, 1120, 1130, 1140, or PH 1111, 1121, 1130, 1140, although other orderings are possible, depending on special circumstances.

The first two courses in this sequence are offered in two versions because of the diversity of backgrounds and preparation of entering students. PH 1111 and PH 1121 are aimed primarily at freshmen with a solid background in the sciences and in mathematics, including calculus. In particular, students in PH 1111 and PH 1121 should be
able to differentiate and integrate elementary trigonometric and polynomial functions, and to interpret these operations in graphical form. PH 1110 and PH 1120 are taught at a mathematically less demanding level and are designed for students concurrently beginning their study of calculus, having had little or no college-level calculus preparation in high school.

The courses in classical mechanics and electricity and magnetism are regarded as essential preparation for many fundamental engineering courses as well as for further work in physics. PH 1130 gives a first introduction to 20th century physics: the theory of relativity, quantum physics, nuclear physics and elementary particles. It is designed to provide a context for the appreciation of present-day advances in physics and high-technology applications. PH 1140 deals in depth with oscillations and waves. Engineering applications of this subject reach all the way from LC circuits and electromagnetic wave propagation in electrical engineering to the vibrations of large scale structures such as machinery and highway bridges in mechanical engineering and civil engineering.

There are several intermediate physics courses that may be of interest to nonphysics majors. PH 2201–2202 give a physicist’s view of mechanics which to mechanical engineering majors may be an interesting and useful complement to the engineering courses in statics and dynamics. The physics courses in quantum mechanics, PH 3401–3402, and solid state physics, PH 3502, may be of great interest to electrical engineering students specializing in solid state electronics. The courses in electromagnetic field theory, PH 2301 and PH 3301, and optics, PH 3504, would provide a valuable background for students in many areas, such as modern communication systems, fiber optics and optical computing. These are just examples; other courses are also available. For specific information on individual courses, students may consult with the course instructor or with the Physics Department advisor or an independent study advisor, see the Head of the Physics Department in Olin 119.

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 2601 Physics Laboratory
PH 3401 Quantum Mechanics I
PH 3504 Optics
IS/P 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 119.

Majors in Physics or Engineering Physics do not qualify for a Minor in 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 2601 Physics Laboratory
PH 3401 Quantum Mechanics I
PH 3504 Optics
IS/P 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.

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For more information, or assistance in selecting a minor advisor or an independent study advisor, see the Head of the Physics Department in Olin 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 106. 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**

A B.S./MBA program is available to outstanding WPI undergraduate students majoring in an engineering or science discipline. A separate and complete application to the MBA program must be submitted. Admission to the Combined Program is determined by the faculty of the Department of Management. The student should begin the curriculum planning process at the time he/she commences his/her undergraduate studies to ensure that all of the required prerequisite undergraduate courses are completed within the student’s four years of undergraduate study. It is recommended that the MBA application be submitted at the beginning of the student’s junior year of undergraduate study. A student in the Combined Program continues to be registered as an undergraduate until the bachelor’s degree is awarded.

Students wishing to do a Combined B.S./MBA must complete the following courses while an undergraduate:

- MG 1100 Financial Accounting
- MG /IE 2200 Financial Management
- MG /IE 2300 Organizational Science
- MA 2611 Applied Statistics I
- MA 2612 Applied Statistics II
- MG /IE 3400 Production System Design
- MG 3600 Marketing Management
- MG 3700 Information Systems Management
- SS 1110 Introductory Microeconomics
- SS 1120 Introductory Macroeconomics

To obtain a bachelor’s degree via the Combined Program, the student must satisfy all requirements for the bachelor’s degree, including distribution and project requirements.

To obtain an MBA via the Combined 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:

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

For more information on this program, contact N. Wilkinson, Washburn 218, (508) 831-5957.

**PRE-MEDICAL, PRE-DENTAL AND PRE-VETERINARY PROGRAMS**

**ADVISOR: J. RULFS**

Planning a program in one of the pre-health professions at WPI should be done in consultation with the WPI faculty pre-health professions advisor, Prof. J. Rulfs, Salisbury Labs 233. Entry into medical or other health professional schools may be accomplished through any major program of study at WPI. However, evidence that the student is interested in medicine and biology must be presented to the professional schools during the application process. For this reason, students, regardless of major, should plan their academic programs to include courses in biology, general and organic chemistry, and physics including laboratory experiences.

The pre-health professions programs at WPI offer a variety of activities which help to inform students about the various opportunities present in the medical professions and which improve their chances of gaining admission to the professional school of their choice.

Students interested in becoming veterinarians should consider applying for admission to the joint B.S./D.V.M. program offered by WPI and Tufts University School of Veterinary Medicine. Students entering this program are guaranteed admission to veterinary school as early as the high school senior year and in addition can complete the entire program in seven years, rather than the traditional eight.

The formalized WPI projects program offers a tremendous advantage to pre-health professional students. Medical, dental, and veterinary schools view independent study and participation in research with great favor. At WPI, all students, rather than a select few, participate in such activities. The IQP and MQP are excellent examples. Most IQPs and MQPs done by WPI pre-health professions students are health-related, and many are done at off-campus medical settings such as the University of Massachusetts Medical Center, the Tufts School of Veterinary Medicine, or various hospitals in either the Worcester area or in San Francisco.

A typical pre-medical or pre-dental program should include:

- Introductory chemistry: 3 courses
- Organic chemistry: 3 courses
- Biology: 3 courses
- Physics: 3 courses
- Mathematics: 3 courses
- English Composition: 2 courses

Science courses should include laboratory segments.

*Check with Sufficiency advisor for use of Humanities and Arts courses in lieu of composition requirement.

Students should consult medical or other professional school catalogs for specific admissions requirements. Students majoring in certain programs may have to utilize all of their electives to fulfill pre-health course requirements and/or may have to take some courses during summer sessions.
Grades in undergraduate courses, especially science courses, are important to medical, dental, and veterinary schools. Applicants usually have to submit a "cumulative quality point average" calculation. Such a calculation is performed by the Registrar upon written request by the student.

Students aspiring to enter one of the health professions should also plan alternative careers. Nationally only about one out of three qualified applicants is accepted into medical school, and veterinary schools are even more selective. Many WPI pre-health students have been successful in their applications to professional schools. However, it is important to realize that all WPI graduates have a degree in a major program of study and are thus well qualified to pursue a career in that alternative area.

### SOCIAL SCIENCE AND POLICY STUDIES

**K. SAEED, HEAD**

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

**MISSION STATEMENT**

The Department of Social Science and Policy Studies offers undergraduate majors in system dynamics; economics and technology; environmental policy and development; and society, technology and policy. In addition, the department is responsible for administering WPI’s two-course requirement in Social Sciences.

The teaching of social sciences differs from engineering in that it must deal with a large variety of empirical manifestations in the face of unreliable and often local theoretical premises. Thus, while a bulk of engineering practice involves applying well known physical principles to the design of physical systems, much time must be spent in social science analysis in recognizing problems, understanding their underlying relationships and developing premises to deal with the stylized facts. Once a problem is recognized, a vehicle of analysis must be developed to understand it and develop a remedial process. The validation of social analysis draws on the well-known principles of the scientific method, although the mechanics of its implementation vary depending on the vehicle of analysis used.

SSPS programs are concerned with the substance and the process of socioeconomic problem solving, especially as related to technological development and public policy. Most socioeconomic problems—e.g., inflation, unemployment, urban deterioration, environmental pollution, income inequality, or infrastructure creation and maintenance—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 system dynamics, economics, sociology, psychology, law and political science. System dynamics exclusively focuses on a computer modeling and experimental analysis approach to problem solving and policy analysis while other areas employ a variety of modeling and analysis methods including system dynamics. The department also 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 differing methods of social data gathering and analysis.

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 such models to establish their validity.
4. An ability to carry out exploratory analysis to arrive at remedial instruments 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 with groups.

SSPS course offerings attempt to address the above agenda by focusing on description and analysis rather than only on prescription. Methodology and its valid practice are covered extensively in the system dynamics courses, while in other offered courses, research methods are integrated with the discipline-related content. Many courses emphasize group work in one form or the other. Item 5 above is addressed through coursework in other departments offering relevant curricula. Interactive Qualifying Project (IQP) and Major Qualifying Project (MQP) offer opportunities for learning the problem solving process in a real world context.

**MAJOR PROGRAMS**

The department offers majors in system dynamics, economics, economics and technology, environmental policy and development, and society-technology and policy.
SYSTEM DYNAMICS
The system dynamics major is aimed at developing the craftsmanship and the multi-disciplinary skills needed for computer modeling and experimental analysis of complex socioeconomic and technical problems encountered in private and public organizations. It prepares students for careers in public and private sector organizations maintaining in-house planning and problem solving groups, as well as for careers in public and private sector consulting firms. The fundamental focus of the program is on system dynamics as a problem-solving methodology and on training students to apply system dynamics to a wide range of problems being experienced by engineering, economic and societal systems. The application areas of the program are designed to create opportunities for students to apply computer modeling and experimental analysis to specific problems, so that they can develop both expertise in those areas and the methodological skills necessary for applying the technique to other application areas. The major responds to the need for integrating specialized skills to address multidisciplinary problems created by the interaction of society and technology.

ECONOMICS AND TECHNOLOGY
Economics has traditionally been viewed as an excellent preparation for careers in law, public service, and general management in business and government. According to the United States Bureau of Labor, employers specifically listed a major in economics as a good background for careers in a wide variety of administrative and sales areas. Students that are beginning careers directly out of college will find that the study of technology will provide an invaluable supplement to their training in economics in many occupations. Future graduates of the department's program in economics and technology will be desired by firms looking for managers possessing the technological knowledge of the engineer and the decision making perspectives and modeling skills of the economist. Examples of such firms include: 1) pharmaceutical companies needing managers to analyze drug markets and interact with chemists and chemical engineers, 2) investment banking houses and brokerage firms needing analysts and brokers with the technological literacy necessary to assess high technology firms and their market prospects, and 3) public utilities needing managers capable of forecasting electricity demands and conducting cost benefit analyses of alternative methods of acquiring generating capacity.

The Economics and Technology major is an ideal preparation for graduate education, particularly the MBA. Study of the functional areas of management and specific managerial skills consume so much of an MBA program that only minimal time remains for study in other important areas including economics. However, a thorough understanding of economics is critical for all types of businesses and government agencies. Moreover, the ability to understand a business firm's technical production processes and products is also important in many areas of Management. Clearly, both halves of the Economics and Technology program complement the preparation for the business world provided by graduate programs in business. The E&T major provides training in areas that are important for success in business but are largely and wholly neglected in graduate business programs. Students enrolled in the Economics and Technology program offered by the Department of Social Science and Policy Studies at WPI will study economic theory and model building at both the micro and macro levels as well as techniques for economic decision making and the collection and analysis of economic data. Macroeconomic theory explains the behavior of the economy in the aggregate, while microeconomic theory deals with the behavior of individual firms, consumers and markets. The economics portion of the program includes well over a dozen courses in economics and related subjects in management and the other social sciences. These cover basic economic theory and its applications in such areas as the environment, health care, industrial organization, fiscal and monetary policy, as well as quantitative methods.

The program’s technical component comprises more than a dozen courses roughly evenly divided between basic science and math preparation and courses in an engineering or science major. The aim is to acquaint students with the work of professionals in the technical discipline, ensure that they are conversant with the field, and familiar with its terminology and basic principles. Course sequences providing this preparation have been identified for twelve engineering and science disciplines, including computer science and mathematics.

ENVIRONMENTAL POLICY AND DEVELOPMENT
During the past decade, the daily news has become increasingly filled with stories of economic stagnation and environmental destruction. As a result, interest in the environment and its impact on households, firms, cities, regions, and nations has been rekindled among students, the public at large, and within private firms and the government.

At the university level, environmental issues can be studied in a number of ways. They can, for example, be studied from a technological perspective via the natural and engineering sciences, or from a policy perspective via the management and social sciences. Indeed, environmental programs at many universities examine environmental issues in precisely these ways. It is unusual, however, for an environmental program to offer a strong education from both the technical and policy perspectives. The Department of Social Science & Policy Studies at WPI fills this gap by offering a baccalaureate degree in the area of Environmental Policy and Development (EP & D). This degree program offers students substantial technical and policy education on environmental issues. An important feature of WPI's EP & D major is its focus on the interaction between the environment and the economy. On June 14, 1992, during the so-called "Earth
Summit” in Rio de Janeiro, the United Nations Conference on Environment and Development adopted Agenda 21, a document that calls upon the nations of the world to “take a balanced and integrated approach to environment and development questions.” The EP & D major has adopted sustainable economic development as one of its organizing themes. That is, many traditional environmental issues are examined through the lens of sustainable development.

The term sustainable development means choosing policies that balance environmental preservation and economic development so as to meet the needs of the present generation without compromising the needs of future generations. The global ecological-economic system is essentially “closed.” This means that, except for the receipt of solar energy from outer space and the dispersion of heat to outer space, the system is self-contained. The people living in the global system use both nonrenewable and renewable resources (which are limited) to produce goods and services that sustain and enhance life on the planet. Unfortunately, the process of creating goods and services also generates pollution that must be dispersed into the land, sea, and air. The amount of pollution that these “sinks” can absorb is also limited.

For the global system to sustain itself indefinitely, renewable resources must not be used faster than the rate at which they can be regenerated, nonrenewable resources (taking recycling into account, which is also a limited process) must not be faster than the rate at which they can be substituted for, and pollution must not be generated faster than the rate at which the system can absorb it. WPI’s program in EP & D 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.

SOCIETY, TECHNOLOGY AND POLICY
The Society Technology and policy major at WPI is designed for those who wish to prepare for a career in which they will deal with our society’s critical problems. Great challenges face our society and many of the major ones stem from the interplay of technology and society. Environment, energy, productivity, population, education, defense, and global competition are all recognized as policy areas in which technological change is playing an important role. To address such problems, policy makers and analysts must be technically literate and familiar with the tools of analysis in the social ills both as a cause and, potentially, as a cure. This is precisely the background and knowledge that the Society, Technology and Policy program seeks to provide.

In the STP program students major in social science and minor in a science or engineering discipline of their choice. Over a dozen technological alternatives are available including: biotechnology, computer science, manufacturing engineering, and management. Students take courses in at least two social science disciplines: economics, political science, psychology, and sociology. The social science coursework will emphasize policy issues and the study of the ways in which science and technology shape society and, conversely, the ways in which social forces affect the development of technology.

As a major in this program, a student will benefit from WPI’s project oriented approach to learning. Students use project opportunities to engage in in-depth research on social policy issues and the interactions between society and technology. They may carry out their projects on the WPI campus, at any number of local agencies or corporations, or at one of WPI’s off campus project programs in the United States and abroad.

Through this interdisciplinary program the student will acquire the social science background needed to understand contemporary public policy, to interpret technical materials produced by physical scientists, engineers and social scientists and to be able to synthesize these materials for policy considerations on the part of government and industry. Graduates of this program will be valuable additions to the administrative or research staffs of a variety of businesses, regulatory agencies, government departments or contract research organizations.

Program Distribution Requirements For The System Dynamics, Society Technology and Policy, Economics, Economics and Technology, and Environmental Policy and Development 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:

<table>
<thead>
<tr>
<th>SYSTEM DYNAMICS</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Requirements</strong></td>
<td></td>
</tr>
<tr>
<td>System Dynamics (Note 1)</td>
<td>5/3</td>
</tr>
<tr>
<td>Other Social Science (Note 2)</td>
<td>5/3</td>
</tr>
<tr>
<td>Management (Note 3)</td>
<td>2/3</td>
</tr>
<tr>
<td>Mathematics/basic sciences/engineering (Note 4)</td>
<td>8/3</td>
</tr>
<tr>
<td>Computer Science (Note 5)</td>
<td>2/3</td>
</tr>
<tr>
<td>Application Area (Note 6)</td>
<td>5/3</td>
</tr>
<tr>
<td>MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

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 analysis.
5. Must include CS1005 and CS2005.
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.
### ECONOMICS AND TECHNOLOGY

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics (Note 1)</td>
<td>3</td>
</tr>
<tr>
<td>Management (Note 2)</td>
<td>2/3</td>
</tr>
<tr>
<td>Other Social Science</td>
<td>1</td>
</tr>
<tr>
<td>Basic Science</td>
<td>2/3</td>
</tr>
<tr>
<td>Mathematics (Note 3)</td>
<td>5/3</td>
</tr>
<tr>
<td>Technical Electives (Note 4)</td>
<td>2</td>
</tr>
<tr>
<td>MQP (Note 5)</td>
<td>1</td>
</tr>
</tbody>
</table>

Total 10

**NOTES:**
1. (a) Must include econometrics, systems analysis, industrial organization and intermediate level microeconomic and macroeconomic theory.
   (b) Must include (1) two courses in environmental economics, the economics of the medical care industry or advanced systems analysis or (2) two courses in fiscal and monetary economics.
2. Must include financial accounting and either financial management or engineering economy.
3. Must include statistics, and differential and integral calculus.
4. Courses must be in science or engineering with a concentration in one discipline.
5. The MQP may be in Economics or in the student’s technical field with the approval of the academic advisor and the departmental Program Review Committee.

### SOCIOLOGY TECHNOLOGY AND POLICY

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Science (Notes 1 and 2)</td>
<td>4</td>
</tr>
<tr>
<td>Minimum Basic Science background</td>
<td>2/3</td>
</tr>
<tr>
<td>Minimum Mathematics background (Note 3)</td>
<td>1</td>
</tr>
<tr>
<td>Technical concentration (Note 4)</td>
<td>5/3</td>
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<tr>
<td>Electives (Note 5)</td>
<td>5/3</td>
</tr>
<tr>
<td>MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

Total 10

**NOTES:**
1. Students must obtain approval of their proposed program from the departmental 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.

### ECONOMICS

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics (Note 1)</td>
<td>3</td>
</tr>
<tr>
<td>Economics and/or Management (Note 2)</td>
<td>1</td>
</tr>
<tr>
<td>Other Social Science</td>
<td>1</td>
</tr>
<tr>
<td>Mathematics (Note 3)</td>
<td>2</td>
</tr>
<tr>
<td>Basic Science</td>
<td>1</td>
</tr>
<tr>
<td>Electives</td>
<td>1</td>
</tr>
<tr>
<td>MQP</td>
<td>1</td>
</tr>
</tbody>
</table>

Total 10

**NOTES:**
1. Must include courses in both micro and macro economic theory at the intermediate level and in international trade and econometrics (available through the Consortium or independent study).
2. Must include financial accounting, MG 1100. May include other relevant management courses as approved by the departmental review committee.
3. Must include differential and integral calculus, and statistics.

### ENVIRONMENTAL POLICY AND DEVELOPMENT

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Minimum Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS &amp; PS (Note 2)</td>
<td>12/3</td>
</tr>
<tr>
<td>Mathematics (Note 3)</td>
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<tr>
<td>Basic Science (Note 4)</td>
<td>2/3</td>
</tr>
<tr>
<td>Technical Concentration (Note 5)</td>
<td>2</td>
</tr>
<tr>
<td>Department Electives (Note 6)</td>
<td>2/3</td>
</tr>
<tr>
<td>MQP</td>
<td>4</td>
</tr>
</tbody>
</table>

Total (Note 3) 10

**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: A Psychological Perspective on Environmental Problem Solving, American Public Policy, Development Economics, Environmental Economics, International Environmental Policy, Introduction to Economic Systems, Legal Regulation of the Environment, Technical Expertise in Governmental Decision Making, 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.
THE SOCIAL SCIENCE REQUIREMENT

To satisfy WPI’s two-course social science requirement, students may take courses in any of the traditional social sciences. They will normally begin by taking one of the introductory core courses listed below:

- System Dynamics
- SS 1503 The Psychology of Decision Making and Problem Solving
- SS 1510 Introduction to Economic and Social Systems
- SS 1520 Dynamic Modeling of Economic and Social Systems

**Economics**
- SS 1110 Introductory Microeconomics
- SS 1120 Introductory Macroeconomics

**Sociology**
- SS 1202 Sociological Concepts and Analysis
- SS 1401 Introduction to Cognitive Psychology
- SS 1402 Introduction to Social Psychology

**Political Science**
- SS 1301 U.S. Government
- SS 1302 American Political Ideas
- SS 1303 American Public Policy
- SS 1310 Law, Courts, and Politics
- SS 1320 Topics in International Politics

**Social Psychology**
- SS 2401 The Psychology of Education
- SS 2405 The Psychological Study of Environmental Issues
- SS 2406 Cross-Cultural Psychology: Human Behavior in Global Perspective

The Second Course in Social Science

In choosing their second course in social science, students confront a choice between taking a second introductory course in another social science discipline, or a more advanced course in the same social science discipline as the first. The department recommends the latter choice. At least two courses in a given field are essential to achieving a firm understanding of the nature of the discipline: its organization, its basic vocabulary, the way in which it approaches the solution of the problems that are its central focus, and how it seeks to explicate the phenomena with which it is concerned. Moreover, the advanced courses available at WPI have substantial empirical components which provide the student with an opportunity to see how social science is applied to the solution of specific public and private policy problems. These courses are listed below.

- System Dynamics
- SS 2530 Advanced Topics in System Dynamics Modeling
- SS 2540 Group Model Building
- SS 3550 System Dynamics Seminar

- Economics
- SS 2111 Social Control of Business
- SS 2125 Development Economics
- SS 3111 Managerial Economics

- Sociology
- SS 1203 Social Problems and Policy Issues
- SS 2207 Creativity and the Scientific Community
- SS 2208 The Society - Technology Debate
- SS 3278 Technology Assessment and Impact Analysis Seminar

- Political Science
- SS 2302 Science-Technology Policy
- SS 2304 Governmental Decision Making and Administrative Law
- SS 2310 Constitutional Law
- SS 2311 Legal Regulation of the Environment
- SS 2312 International Environmental Policy

- Social Psychology
- SS 2401 The Psychology of Education
- SS 2405 The Psychological Study of Environmental Issues
- SS 2406 Cross-Cultural Psychology: Human Behavior in Global Perspective

These advanced or depth courses deal with a wide variety of subjects: system dynamics modeling and experimental analysis, government regulation of business, environmental law and economics, educational psychology, technology assessment and environmental policy and decision making, among others. This element of application in the depth courses adds greatly to students’ interests in the course and their understanding of the capabilities and usefulness of the subject.

Students are advised to take both of their social science courses in the same discipline so that they may take a depth course that will provide an opportunity to study social science of specific and direct relevance to their Interactive Qualifying Projects (IQPs). The department believes that it is critical for students to forge as close and direct a link as possible between their social science preparation and IQP.

The IQP relates science and technology to society. It aims to make students sensitive to general social problems, aware of societal-humanistic-technological interactions, able to analyze these interactions and to make better judgments and policy recommendations. Given the objective of the IQP, it is not surprising that many involve analysis of social problems and the evaluation of policy options. Typically, knowledge of both technology and social science are required for effective handling of such IQPs. But in many cases, the critical skills lie in the area of social science. Technology provides the base-line level of information required to assess an impact or to evaluate options. However, the manner in which society responds to technical change is a function of our economic and political systems, of individual perceptions, attitudes and values, and the interactions of individuals and groups. All of these are the subject matter of social science. Their understanding is essential for projects that analyze societal-technological interactions and examine social policy issues, whether directly linked to technological developments or not.
The most important contribution which the study of social science can make to the education of engineering and science students is to create an awareness that knowledge of social science is vital in analyzing a wide range of problems and in making many types of decisions. It is important that, in the future, engineers and scientists not approach social impact problems guided solely by their background in technology, ignoring the previous contributions of the social sciences in these areas. The primary goal of the social science requirement is to leave engineering and science students with the recognition that social science knowledge is useful and accessible and that they are capable of mastering its tools, comprehending its approaches and applying these tools to practical problems.

If this goal is to be realized, it is highly advisable that students link their study in social science to their Interactive Qualifying Projects. The department recommends that students begin with an introductory course late in the freshman or early in the sophomore year, and follow that with an applied depth course in the sophomore or early in the junior year when the IQP topic has been identified.

**COURSE SEQUENCES IN SOCIAL SCIENCE**

To aid students in selecting appropriate sequences of introductory and applied courses to satisfy their social science requirement, the department has identified logical course sequences in the areas listed below.

**SYSTEM DYNAMICS**

Introduction to Economic or Social Systems (SS 1510) followed by SS 1520 Dynamic Modeling of Economic and Social Systems provides students with a sequence of two courses in system dynamics. The first course introduces the students to the systems thinking perspective and the techniques of modeling and experimental analysis using computer simulation. The second course deals with problem solving using system dynamics modeling. These two courses provide the basic skills for applying the system dynamics method to IQP or MQP projects. System Dynamics is an expanding process in K-12 education, this course sequence would also greatly help aspiring high school teachers to apply system dynamics in facilitating learning in their respective subject areas. For a more technical treatment of the subject, the two course sequence may include Dynamic Modeling of Economic and Social Systems (SS 1520) followed by Advanced Topics in System Dynamics Modeling (SS 2530).

**BUSINESS AND GOVERNMENT**

Introductory Microeconomics (SS 1110) followed by either Social Control of Business (SS 2111) or Managerial Economics (SS 3111) provide students with two sequences of courses in microeconomic theory and applications. The first course in either sequence covering introductory microeconomics is intended to give the student a basic understanding of how a market economy functions. It shows how the demand and supply for the inputs and outputs of the production process interact in the marketplace to determine the prices of goods, the wages of labor, the amounts and types of labor and capital utilized in production and the quantities of goods and services produced. The two follow-up courses to microeconomic theory apply this understanding to an analysis of economic issues from the perspective of both the public interest (Social Control of Business, SS 2111) or the private interest (Managerial Economics, SS 3111).

Social Control of Business (SS 2111) examines government policies toward business. The principal concerns are the efficiency of the mixed free enterprise economy and the policies available to government to improve economic performance. The course discusses such alternatives as the direct regulation of prices and outputs and the use of the antitrust laws to maintain competition. Social Control of Business should be taken by students who wish to study or do projects on current economic issues such as the failure of American industry in international competition and the lagging rate of technological change in the United States.

In the second course sequence, Introductory Microeconomics or Introduction to Economics is followed by Managerial Economics, SS 3111. The emphasis here is on the decision making of business firms. Knowledge of how prices and outputs are determined indifferent types of markets is used to analyze how business firms can determine their own prices and outputs to achieve their goals. This course will be of interest to anyone concerned with the effective management of business enterprises. The tools of decision making developed in this course find application in a wide range of IQPs. Cost analysis, investment decisions, and the forecasting of trends in consumption, production and prices are required in many IQP's dealing with energy, risk analysis, and economic growth and development.
A two-course sequence in Cognitive or Social Psychology is ideal preparation for IQPs that require an understanding of how individuals or groups think when faced with social and technological problems. SS 1401 (Introduction to Cognitive Psychology) and SS 1402 (Introduction to Social Psychology) are alternate introductions to experimental psychology. SS 1401 emphasizes the mental processes that individuals apply to perception, memory, learning, judgement, and problem-solving tasks and their implications for education and engineering design. SS 1402 is concerned with how people think about, feel for, and act toward other people, and covers such topics as social influence, altruistic behavior, aggression, gender differences, stereotyping and prejudice, and small group decision making.

The Psychology of Decision Making and Problem Solving (SS 1503) provides students an opportunity to improve many of the cognitive skills relevant to IQPs and MQPs, including memory, problem solving, reasoning, decision making, and intelligent criticism.

Either SS 1401 or SS 1402 followed by SS 2401 (The Psychology of Education), provides a solid background for students who plan to conduct IQPs in educational settings, from pre-school through college. SS 2401 covers such topics as student diversity, the learning process, motivation to learn, and techniques for evaluating student learning. Current issues in higher education (particularly technological education) are emphasized.

The two-course sequence SS 1402 and SS 2406 (Cross-Cultural Psychology: Human Behavior in Global Perspective) is especially designed for IQP students preparing to work at international project centers, International Scholars, and students interested in the global aspects of science and technology. SS 2406 introduces students to the wide variety of social and cultural influences that shape human behavior in different parts of the world, with particular attention paid to cultural influences on technology development and transfer.

Students interested in new approaches to environmental problems should consider taking SS 1401 followed by SS 2405 (The Psychological Study of Environmental Issues). SS 2405 traces the root causes of environmental problems to basic human thought processes and explores the argument that successful environmental policies must be based on an understanding of how individuals think about the environment, how pro-environmental behavior is related to environmental attitudes, and how people respond to environmental information and policies. The course emphasizes the application of psychological knowledge to the development of innovative solutions to problems such as global warming, ozone depletion, species extinction, and energy and resource conservation.

Many IQP projects center on issues of social impact, technology assessment, or addressing a social problem. Some address issues specifically in the society-technology debate regarding the cultural and social trends associated with the emergence of a “Technological” or “Post-industrial” society. The following courses have been developed as background material for such projects: Many are also core courses in the curriculum designed for Society-Technology Majors.

The typical entry level course for those interested in The Technology-Society Debate (SS 2208), Science and Creativity (SS 2207), or Social Problems and Policy Issues (SS 1203) is the Introduction to Sociological Concepts (SS 1202). However, there are two other courses that are acceptable alternatives in preparing for (SS 1203) Social Problems and Policy Issues. These are Introduction to Social Psychology (SS 1402) and U.S. Government (SS 1301). The Introduction to Social Psychology (SS 1402) is also a good alternative preparation for Science and Creativity (SS 2207).

The two-course sequence, SS 1202 (Sociological Concepts) and SS 3278 (Technology Assessment and Impact Analysis Seminar), is also a fine approach to take if someone is interested specifically in Social Impact Analysis. Those interested in extending the SS 1202 (Sociological Concepts) and SS 2208 (Society-Technology Debate) with more work on a related theme should consider taking the seminar on Impact and Assessment Seminar (SS 3278) or Science-Technology Policy (SS 2302).

Three courses introduce students to the analysis of public policy: SS 1301, U.S. Government; SS 1303, American Public Policy; and either SS 2302, Science-Technology Policy, or SS 2304, Governmental Decision Making and Administrative Law. This sequence is designed for students who want to obtain an understanding of American government, its institutions, and the factors affecting public policy. The courses would be especially useful for students whose IQPs will address a public policy issue or some problem that requires a response from government. In addition, the courses will impart an appreciation for our political heritage and the values which shaped our constitutional structure.

The political environment for science and technology has become extremely complex during the last few decades. Government directly supports over half of the nation’s research and development. It also regulates the use of many technologies, including nuclear power, biotechnology, and manufacturing processes which potentially harm the environment. Moreover, scientists and engineers are frequently called upon to help government solve problems. They often find themselves uncomfortably in the midst of political controversies.
These courses would shed some light on the mysterious processes of government. By enabling students to critically assess the performance of government and to articulate their own policy preferences, the courses would eliminate one barrier preventing WPI students from contributing to the public process.

**Curriculum Guidelines for System Dynamics**

Recommendations for complying with the program distribution requirements (10 units) are described below. To earn a Bachelor of Science (B.S.) degree in System Dynamics, students must complete 15 units of coursework. In addition to the requirements below, one must complete the Sufficiency (2 units), the Interactive Qualifying Project (1 unit), free electives (5/3), and physical education (1/3).

Specific course recommendations for complying with the program distribution requirements are given below. These recommendations are intended to offer flexibility while preparing students for careers in system dynamics.

**System Dynamics (5/3)**

Students can choose from among the following 6 courses in system dynamics:

- SS1510: Introduction to Economic and Social Systems
- SS1520: Dynamic Modeling of Economic and Social Systems
- SS1503: The Psychology of Decision Making and Problem Solving
- SS2530: Advanced Topics in System Dynamics Modeling
- SS2540: Group Model Building
- SS3550: System Dynamics Seminar

**Other Social Science (5/3)**

It is recommended that the requirement for microeconomics or macroeconomics be satisfied with either SS1110 or SS1120, although higher level economics courses are also possible. It is recommended that the requirement for cognitive or social psychology be satisfied with SS1401 or SS1402, although higher level psychology courses are also possible. The public policy requirement can be met by taking one of the following courses: SS1301, SS1303, SS2302, SS2304, SS2312. The other two social science courses are free electives and students can take any additional four courses in economics, sociology, political science and law, psychology, and system dynamics.

**Management (2/3)**

The requirement for organizational science may be met by taking one of MG/IE2300 or MG/IE3351. The second management course is a free elective.

**Mathematics and Basic/Engineering Science (8/3)**

The requirement for differential and integral calculus may be met by completing the calculus sequence through MA1024. Higher level math courses or other basic science or engineering courses may be substituted if students complete MA1024 without taking the full sequence MA1021-MA1024. It is recommended that the requirement for differential equations be met by course MA2051 and the requirement for numerical analysis be met by MA3255/Cs4031. Once the math requirements are met, students may take any combination of additional math, basic science, or engineering courses to complete the 8/3 unit requirement. Those pursuing computer science as an application area should take CS2022 to be able to follow upper level courses in the application area. It is recommended, but not required, that students take PH1110 and PH1120 as preparation for ES3011.

**Computer Science (2/3)**

CS1005 and CS2005 are recommended.

**Application Area (5/3)**

A minimum of 5/3 units of integrated coursework is required to satisfy this requirement. Often students focus their applied courses in a particular area such as those noted below. Other focus areas are possible but must be approved by the student’s academic advisor and the Department’s Undergraduate Committee early in the student’s program. Suggested courses for 12 application areas are given below. There is some flexibility needed in the selection of these courses since system dynamics covers a wide range of policy agenda. The student must take 3 additional courses to get a minor in an application area. Requirements of the respective departments are to be met in the course selection for the minors.

**Economics**

Select 3
- SS1110 Introductory Microeconomics
- SS1120 Introductory Macroeconomics
- SS2110 Intermediate Microeconomics
- SS2120 Intermediate Macroeconomics

Select 2
- SS2125 Development Economics
- MG/IE2850 Engineering Economics
- SS2111 Social Control of Business
- MG3800/SS3111 Managerial Economics
- SS2117 Environmental Economics

**Project Dynamics**

Required
- CE1030 Civil engineering and Computer Fundamentals

Select 3
- MG2101 Management Accounting
- CE3020 Project Management
- CE3021 Cost Estimating, Scheduling and Control
- CE3022 Legal Aspects in Design and Construction
- MG/IE2200 Financial Management
- SS/CE 4000 Independent Studies in Project Management

**Engineering Systems**

Required
- ME1800 Materials Selection and Manufacturing process

Select 4
- ME3311 Dynamics of Mechanisms and Machines
- ME3321 Dynamic Modeling
- ME3422 Environmental Issues and Analysis
- ME3820 Computer-Aided Manufacturing
- MG/IE3400 Production System Design
- MG/IE3440 Information Systems Management
- MG3700 Information Systems Management

**Public Policy**

Select 2
- SS1301 US Government
- SS1303 American Public Policy
- SS1310 Law Courts and Politics
- SS1320 Topics in International Politics

Select 3
- SS2111 Social Control of Business
- SS2125 Development Economics
- SS2302 Science-Technology Policy
- SS2304 Government Decision Making and Administrative law
- SS2311 Legal Regulation of environment
- SS2312 International Environmental Policy
Fire Protection Engineering
Required
FP3070 Fundamentals of Fire Safety Analysis
MG/IE3501 Management Science II: Risk Analysis
Any other course and Independent Studies in Fire Protection Engineering

Environmental Policy
Select 2
BB2040 Principles of Ecology
CE3059 Environmental Engineering
CE3070 Urban and Environmental Planning
CE3074 Environmental Analysis
CM3910 Chemical and Environmental Technology
CM3920 Air Quality Management
ME3422 Environmental Issues and Analysis
Select 3
PY2717 Philosophy and Environment
SS2117 Environmental Economics
SS2125 Development Economics
SS2311 Legal Regulation of Environment
SS2312 International Environmental Policy
SS2405 The Psychological Study of Environmental Issues

Computer Science
Select 4 or more
CS2223 Algorithms
CS3041 Human Computer Interaction
CS3733 Software Engineering
CS4241 Webware: Network Information Systems
CS4341 Intro to Artificial Intelligence
CS4431 Principles of Database Systems
Any other course and Independent Studies in Computer Science
Select 1 or more
MA2210 Mathematical Methods in Decision Making
MA4255 Numerical Analysis II
MA4411 Numerical Solutions to Differential Equations

Infrastructure Planning
Select 2
SS1120 Introductory Macroeconomics
SS2120 Intermediate Macroeconomics
SS2125 Development Economics
CE1030 Civil engineering and Computer Fundamentals
Select 3
CE3020 Project Management
CE3021 Cost Estimating, Scheduling and Project Control
CE3022 Legal Aspects in Design and Construction
CE3070 Urban and Environmental Planning
CE4024 Real Estate Development

Society-Technology Studies
Select 5
SS1202 Sociological Concepts and Comparative Analysis
SS1402 Introduction to Social Psychology
SS2208 The Society – Technology Debate
SS2302 Science-Technology Policy
SS3278 Technology Assessment and Impact Analysis Seminar
CS3043 Social Implications of Information Processing
HI233 History of Science from 1700
HI3331 Topics in Science, Technology and Society

Transportation Planning
Select 3
CE3050 Highway Engineering and Planning
CE3051 Transportation Systems
CE3070 Urban and Environmental Planning
CE3074 Environmental Analysis
CE4071 Land Use Development and Controls
CE3020 Project Management
Select 2
SS1110 Introductory Microeconomics
SS1120 Introductory Macroeconomics
SS2110 Intermediate Microeconomics
SS2117 Environmental Economics
SS2120 Intermediate Macroeconomics
SS2125 Development Economics

Electrical Power Systems Planning
Select 2
SS1110 Introductory Microeconomics
SS1120 Introductory Macroeconomics
SS2110 Intermediate Microeconomics
SS2120 Intermediate Macroeconomics
Select 3
EE3601 Principles of Electrical Engineering
EE4502 Analysis of Large Scale Electric Power Systems
CE3070 Urban and Environmental Planning

Model Analysis
Select 5
ES3011 Control Engineering I
ES4012 Control Engineering II
MA2210 Mathematical Methods in Decision Making
MA4255 Numerical Analysis II
MA4411 Numerical Solutions of Differential Equations
Independent studies in model analysis

Major Qualifying Project (3/3)
The MQP is expected to provide an integrative capstone experience in system dynamics. Students must complete an MQP that applies system dynamics modeling or methodology to the student’s chosen application area.
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 MQPs 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 insure the selection of an appropriate IQP/MQP.

SOCIAL SCIENCE MINORS

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, sociology, political science (and law), psychology, and system dynamics. 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 disciplines 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 SS 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:
SS 1110—Introductory Microeconomics;
SS 1120—Introductory Macroeconomics;
SS 2210—Intermediate Microeconomics; and
SS 2120—Intermediate Macroeconomics.